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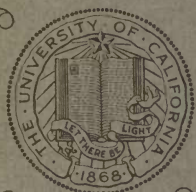


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ELEMENTARY  
PHOTO-MICROGRAPHY.







POLARISCOPE.



Coumarin.  $\times 18$ .

Taken by incandescent gas on Autochrome plate. Exposure,  $1\frac{1}{2}$  hours.

# ELEMENTARY PHOTO-MICROGRAPHY

BY

WALTER BAGSHAW.

FELLOW OF THE ROYAL MICROSCOPICAL SOCIETY.

*WITH FIFTY-SEVEN ILLUSTRATIONS BY THE AUTHOR.*

[ALL RIGHTS RESERVED.]

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## OPINIONS OF THE PRESS.

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### "NATURE."

"The object of the book is fulfilled, and it will form, to those who have a microscope of simple construction, or who, having a camera, wish to apply it for microscopic work as well, a most useful guide. The illustrations are in all cases of a high order, and have been selected, not merely as pictorial examples of photo-micrographic work, but, so far as possible, to bring home to the student the difficulties to be encountered and the results to be attained."

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---

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" It is easy to follow the instructions here given, and the illustrations set before the student high ideals."

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" It will show the way to many a well-spent instructive evening."



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" As an elementary book, Mr. Bagshaw's is all the better for not going too far; indeed, it is just what the beginner wants—concise, clearly written, accurate."

---

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" Puts the matter very clearly as to the taking of photographs through a microscope, so that the beginner's interest is stimulated, and not diminished, as he peruses the manual."

---

" PHARMACEUTICAL JOURNAL."

" The object of this work is to interest and instruct the beginner who wishes simply to learn how to take photographs through a microscope without the expensive appliances necessary to a proper appreciation of the large text books on photo-micrography. Mr. Bagshaw's book appears thoroughly well adapted to this excellent purpose."



## PREFACE.

---

**B**OOKS on photo-micrography, although numerous, are chiefly both expensive and perplexing, covering as they do much extraneous ground that has little or no interest for the beginner who wishes simply to learn how to take photographs through a microscope. Indeed, some of the works devote far more space to the description of various microscopes and accessories than to the elementary information generally desired. Others, again, specify expensive appliances beyond the reach of an ordinary person, so that the reader is deterred from taking up the subject at all.

Now, instead of filling the novice with dismay at the difficulties to be encountered, it is my intention to make the matter so easy that he may be encouraged to proceed.

When lecturing in different towns, I have been surprised to find what an amount of interest could be aroused in working men, many of whom have been stimulated to commence photo-micrography, and have sent me specimens of their early attempts along with expressions of gratitude for directing them to a pursuit far more satisfactory than some which previously occupied much of their leisure.

A list of books upon the scientific side of the subject will be given to enable the amateur to pursue his study with more accuracy and more efficient apparatus than are contemplated for beginners with limited purses and scanty leisure.

I am aware that some of the methods recommended are not in strict accordance with the practice of scientists, but I am not writing for experts in possession of high-class apparatus, but for beginners, and I do claim that an amateur with simple apparatus may produce results which, though not perfect, are good and acceptable for nearly all purposes. A doctor, for example, who may wish to photograph certain specimens of only temporary interest, is enabled to do so by simple means perhaps already at command, and with sufficient exactitude to serve his purpose, even with high powers, whilst with low powers he need not be ashamed of comparing results with the best.

Many of the original prints for illustrations in this book have been shown at the exhibitions of the Royal Photographic Society, and all were taken with objectives supplied with student's microscope.

WALTER BAGSHAW.

*Moorfield House, Birkenshaw,  
near Bradford.*

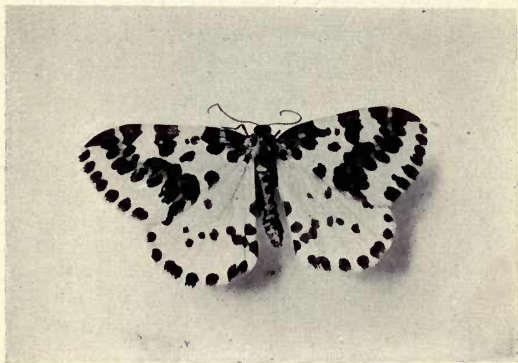


ELEMENTARY PHOTO-MICROGRAPHY.  
PLATE I.

PHOTOGRAPHED WITHOUT A MICROSCOPE.



Shell.  $\times 2$ .



Magpie Moth. Natural size.



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## CHAPTER I.

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### INTRODUCTORY.

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PLEASURES AND ADVANTAGES OF PHOTO-MICRO-GRAPHY.—CAMERA LUCIDA.—CIRCULATING SLIDES.—THE LITTLE SPECIAL APPARATUS NEEDED. — USE OF EYEPIECES. — FIRST ATTEMPTS.

Although the sense of sight enables us to see the many forms around us, there is a world as absolutely invisible to the unassisted eye as the familiar objects of life are invisible to the blind. To those who have eyesight, however, the microscope bestows as great a power of vision as the gift of sight would bestow upon the blind, for it enables them to penetrate the secrets of nature's realm, which without such assistance would for ever remain a mystery.

*Intro*

A very small magnification will often reveal details of construction sufficient to call forth exclamations of surprise ; and, indeed, with microscopists it is a matter of common knowledge that whole insects or parts of plants viewed under a low power will excite more astonishment than the resolution of a difficult diatom under the very highest power. For instance, a spider magnified ten times seems

more wonderful to the uninitiated than the markings of *Amphipleura pellucida* magnified 3,000 times. It is only when the *tyro* attempts to obtain these results himself that he realises the difficulties.

Now, the possessor of a microscope has three ways of showing the special objects of his study to his friends. Firstly, he may exhibit the mounted specimens in the ordinary way, when every individual must of necessity look down the tube of the microscope; or, secondly, he may attach the microscope to a lantern and throw the enlargement upon a screen visible to all; or, thirdly, he may photograph the objects through the microscope, and thus obtain a permanent and ever available record.

It is only with the last of these methods that we have to deal at present, and it is taken for granted that the reader is already familiar with the use of the microscope, since it is much easier to instruct the microscopist in the mysteries of photography than it is to teach the amateur photographer the uses of the microscope. If the reader, then, is not conversant with the microscope, he is recommended to study some good textbook on the subject before attempting to photograph through an instrument he does not understand.

But there are many microscopists who are also photographers, although they may never have tried

the special branch of photo-micrography. To such there is a fund of pleasure in store. As a fascinating pursuit it has no equal. Independent of weather, scenery, and sunshine, the photographer may be seated at a comfortable fireside by gaslight and produce pictures both marvellous and beautiful. Every article at hand is capable of being pressed into service, or if the operator dislike the preparation of his own objects, he has at command for a small sum about 40,000 fine specimens of infinite variety, which can be sent by post from the circulating departments of Mr. C. Baker, and Messrs. Watson and Sons, of Holborn, London.

From his negatives the worker may make both prints and lantern slides, and so provide a feast of entertainment and instruction for himself and his friends.

But the beginner is warned against letting the mere pursuit of pleasure keep him from the educational advantages of systematic work. Hence, instead of making desultory efforts, he is strongly advised to take some special subject and master it before proceeding to another. For instance, he may select plant life, beginning with the simple cell, modes of cell growth, shapes of cells, cell contents, and so following on to the various modifications in highly-organised plants: Seeds, pollen, flowers, and sections of stems are also interesting



objects to be photographed, the study of which should be continued with their *delineation*.

Thus pleasure and knowledge will go together, and every step will prove an incentive to further progress.

On the other hand, if the worker takes up the matter as one merely for amusement, he is not likely to master the difficulties that will present themselves sooner or later, failing which he is the more likely to get tired and discouraged.

The business man as well as the professional man will find endless ways of turning the microscope to profitable account, when once the art of illumination and knowledge of correct exposure are overcome.

The telescope and spectroscope used in connection with the camera have been made to yield most important facts; but **probably no branch of the photographic art has received more extended application or given more valuable results than that of photo-micrography, which enables the microscopist to secure a wealth of detail from the minute forms of life quite impossible by any system of sketching through a camera lucida.**

Think of the advantages to be derived from a photograph when any disputed point arises, as it often does, in the structure of an organism. One observer says he sees a certain formation, while another sees something quite different.



The point of focus, nay, even the illumination, may make all the difference; and without tangible evidence in support of one's contention, a verbal dispute may continue indefinitely. Here a picture of the matter in question at once puts the disputants on common ground, tells if they are taking the same standpoint, and enables them to join issue in a rational way or agree on the cause of divergent opinions.

Then the saving of time to one needing illustrations is immense. Fancy the labour undertaken by some conchologists in sketching the thousands of teeth in the "tongue" of a snail! Half an hour with microscope and camera will secure better results than a month's labour without the aid of camera.

For educational purposes microscopic photography promises great future development, especially in recording the movements and growth of disease germs, as shown by aid of the cinematograph.

It is a great mistake to suppose that the value or interest of living objects is in proportion to the number of feet and inches they occupy in space. The mystery that surrounds these apparently insignificant forms becomes a source of pleasure equal to any depicted in pages of romance, and the origin of life, its reproduction

and duration, become more than futile academic questions.

In every direction there are unknown facts awaiting discovery, and every diligent student, even if an amateur, will find a reward.

Many persons confuse the terms photo-micrography and micro-photography, so it may be well to explain that these are by no means identical. A micro-photograph is a picture of a large object reduced to microscopic size: such, for instance, as York Minster shown the size of a pin-head, whilst a photo-micrograph is a magnified view of a tiny object—the photographs in each case being reduced or enlarged through the microscope.

The results of photo-micrography (pronounced foto-mi-krog-ra-fi) are indisputable, and are far more faithful than any sketches made by the most skilled artist.

Some of the beautiful pictures drawn by means of the camera lucida, and used as illustrations of microscopic objects, stand only in the same position as faked photographs, for the objects themselves never appear trimmed up in such a mechanical manner, hence the camera lucida, that did so well for our fathers, is now a thing of the past, except where simple outlines only are wanted.

Dr. Bousfield writes very emphatically on this subject when he points out that the average

microscopist cannot be free from the "personal equation," which plays so important a part in the registration of scientific observations, and is one of the most fruitful sources of error in such work. Another authority, Cole, also names the imperfections of drawings, however clever, whilst claiming for the photo-micrograph freedom from all defects, colour alone excepted. The dominating element of accuracy should be borne in mind by all photo-micrographers.

Some years ago, even in our large cities, there were few persons capable of producing good photo-micrographs, while to-day they are produced in every branch of science.

In 1891 I had occasion to require some photo-micrographs of sand, but, to my surprise, I was informed that in a city of 400,000 inhabitants only two or three persons outside the Medical School were competent to do the work.

There is no reason why the art should be confined to the select few, for, after all, the mysteries are not so great that they may not be lessened by a few preliminary trials, one or two failures being sufficient to indicate the direction in which an alteration should be made. The apparatus need not be at all costly in order to produce good results, although for high-class scientific research everything must necessarily be of the best.

Consequently, for the purpose of this book, a special room, with massive foundations, in a special district free from the vibration of passing vehicular traffic, monochromatic and electric or limelight, the heliostat for sunlight, expensive apochromatic lenses, or even specially-corrected microscope objectives, will not be requisitioned for carrying out any of the instructions hereinafter given, but only such simple apparatus as the ordinary photographer possesses, with the addition of a microscope. Indeed, for low power work, a camera, a paraffin lamp or lantern, and a few home-made articles are all that are essential, no microscope being required, as the operation is one of simple enlargement.

The adaptability of a quarter-plate camera for all purposes may be seen from the fact that anything from the smallest bacteria, or the most difficult test diatom, to a five-shilling piece, in fact anything within the range of a microscope, may be taken with a camera extension varying from 3in. to 10in.

Moreover, it is desirable that the worker should have the whole of his apparatus within easy reach during the operations of centring, illuminating, and focussing the specimen without change of position, and with long camera extension this is not possible.

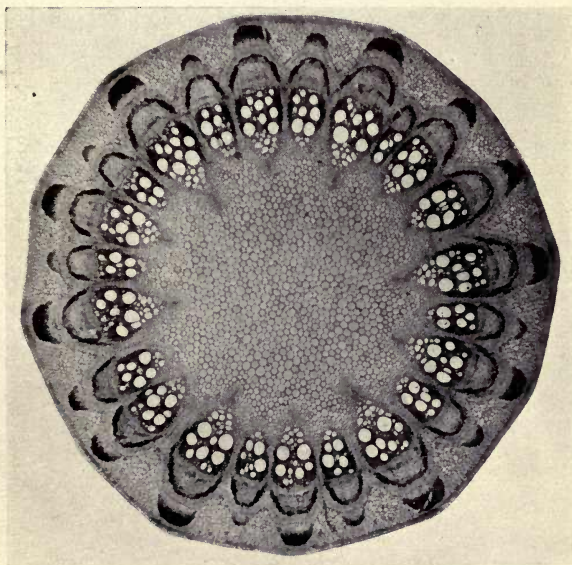


ELEMENTARY PHOTO-MICROGRAPHY.  
PLATE II.

TAKEN BY DIRECT LIGHT.



Section of Human Tongue. 3in. objective. No condenser. "A" eyepiece.  
Chromatic plate. One minute.  $\times 16$ .



Section of Clematis Stem. 3in. objective. Rapid plate. "A" eyepiece.  
One minute.  $\times 14$ .



The whole of the processes hereinafter described are intended to be carried out by artificial light.

There is a difference betwixt the visual and the actinic foci; objectives corrected for photography are sold, but ordinary objectives made by good firms give results not to be despised. Even with high powers tolerable negatives can be obtained, and the brain work of a practical manipulator will often compensate for lack of expensive apparatus.

#### USE OF EYEPieces.

The use of eyepieces is condemned by some writers without much reason. If the eyepiece be not used, a long extension of camera is needed, whereby the apparatus becomes troublesome, and the result is not one jot better than when the eyepiece is employed. The loss of light occasioned by its use is more than compensated for by the compactness of the arrangement, whereby the operator may see or control the whole of his focussing and lighting from one position. A trifle longer exposure is of no moment to a beginner, since the time lost in this way is saved in the facilities offered for focussing. The errors of objectives also are corrected by eyepieces, and good results can be obtained when using them for photographic as for visual purposes. The C eyepiece, although giving great power of enlargement, is not recommended when a low power will do. Yet the writer



has been able to get capital results with C eyepiece when the same magnification had been obtained by a low eyepiece and a high objective with less success.

The magnification of the eyepiece remains the same, irrespective of tube length, but the penetrating power of the objective, or depth of focus, decreases with the increase of both numerical aperture and magnifying power, inversely as the N.A. and also inversely as the square of the magnifying power; from which it will be seen that a low power, such as a 2in., will focus and photograph all the different planes of a thick specimen more clearly than a higher power would do. Therefore, when only good outline and principal points of a coarse object are needed, use always the lowest power sufficient to give the desired details; but for resolving the structure of any particular plane in the specimen and getting all detail possible, then use an objective with a large N.A. Of two objectives having the same power but different in numerical aperture, the one with the largest N.A. will show the greatest detail.

Remember that clearness of definition must never be sacrificed for the sake of a larger picture. A crisp negative may be enlarged, whilst a larger image wanting in sharpness is valueless.

For dark ground illumination and for polariscope, the eyepiece may be dispensed with at the



sacrifice of magnification. Great care, however, must be exercised when not using the eyepiece, or the reflection from the interior of the body tube will manifest itself in the form of a bright central spot on the negative.

The use of an eyepiece removes this entirely, but by way of object lesson let the reader take a microscope that is not dead blacked inside the tube, and throw the image of an object on to a sheet of paper. After getting even illumination with the eyepiece in position, remove the eyepiece, and immediately a bright central spot of light will appear on the paper. If the paper be now moved to or from the end of the microscope, the bright spot of light will gradually expand into a bright ring of light, and then resolve itself into a point again. The whole surface of the illuminated disc is, of course, much more brilliant without the eyepiece, reducing exposure considerably, yet the defect in uniformity of illumination would spoil the negative. On replacing the eyepiece the brightspot of light vanishes, and the whole disc is equally lighted, though not so brightly as before.

A tube of black velvet, plush surface inside, made to slip into the body tube of microscope, will be effective in preventing glare or flare spots when no eyepiece is employed.

First attempts should be made with well-defined objects possessing contrast, such as the section of a stem, rather than with those that are very transparent all over.

## CHAPTER II.

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### THE MICROSCOPE USED AS A MAGIC LANTERN.

Enlargements of minute objects may be shown to audiences either by ordinary lantern slides or through the projection microscope attached to an optical lantern, neither of which, in all probability, does the amateur possess ; yet absolutely no extra apparatus is needed by the owner of a microscope in order to show his slides to a small number of persons at one and the same time, since the microscope can readily be turned into a magic lantern by using it in a horizontal position.

In this way infusoria, diatoms, water fleas, and the larger inhabitants of stagnant water can be shown in motion, and very entertaining it is to watch their movements over the screen.

The brilliant and ever-changing colours of polariscope objects can also be shown, though the largest and most effective pictures are got from stained sections of plants, insects, and similar slides.

To those who care to make the experiment a few hints may be of service. First get a sheet of stout cardboard about 12in. square to act as a screen, and place it in an upright position against a few books piled up behind it. Now place the

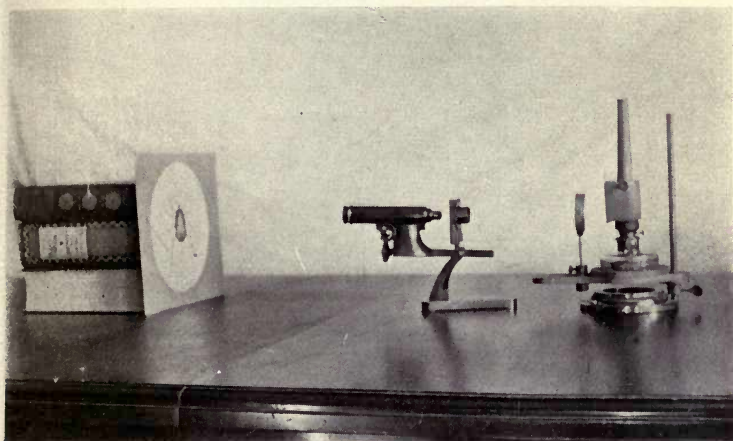
microscope in its horizontal position about a foot away from the screen, first having swung the mirror on one side and removed the substage condenser. Put in the A eyepiece and a 2in. objective for a start, and focus on to a suitable slide on the stage of microscope. Then lower the room lights and bring round the oil lamp and bull's-eye, and adjust them so that a set of horizontal parallel rays is projected through the slide to be examined into the tube of microscope.

A disc of light will immediately appear on the cardboard, but probably brighter in one part than another, in which case the light, or the bull's-eye, or both, should be slightly moved till the illumination of the disc is perfectly uniform in brightness.

Having got this effect, see that the object is in the centre of the field, when a little focussing will bring it into sharpness and make it visible to all.

If the substage condenser and a higher power be used, the cardboard may perhaps have to be brought nearer to the eyepiece, and a sheet of ground-glass between the light and the substage condenser will often make a wonderful difference in securing even illumination. The only difference betwixt enlargements made in this manner and pictures in photo-micrography is that for photographic purposes the magnified image is received on the ground-glass screen of a camera instead of on a cardboard sheet.





Microscope used as a magic lantern.  
FIG. 28.



### CHAPTER III.

---

HOW TO MAKE A SIMPLE MICROSCOPIC OUTFIT.—  
LENS ADAPTER FOR CAMERA.—HOW TO TAKE  
A PHOTOGRAPH SAME SIZE AS OBJECT WITH  
ORDINARY PHOTOGRAPHIC LENS.—TILTING  
TABLE FOR CAMERA IN A VERTICAL POSITION.

Camera benches are catalogued at all prices from £5 to £60, exclusive of microscope; yet an efficient microscope and camera bench combined may be made, capable of working up to high powers, at a small cost, and it will possess the essentials of the more expensive instruments. In fact, the apparatus shown in the illustrations described hereafter will enable one to photograph a very wide range of objects.

To one who can do his own woodwork, the only article to be purchased is a short tube made to receive a full-sized eyepiece at one end and an ordinary objective at the other. The complete stand might be put on the market at a selling price of about 20s., which would probably be an inducement for some photographers to try another branch of an interesting hobby.

Fig. 1 is a photograph showing the whole of the parts in position and ready for work.

In describing the general arrangement, I may say that the baseboard may consist of only one

piece, or of two—preferably two—pieces of wood, each  $\frac{5}{8}$  in. thick, the upper piece being 21 in. long  $\times$  5 in. wide, free to swivel on a centre to avoid the inconvenience of putting the head between the camera and eyepiece whilst focussing.

Carrying, as the baseboard does, both lamp and microscope, the adjustments are not altered while turning it on its pivot. The lower piece is widened at one end to suit the camera used—a quarter-plate is best—and has flanges at each side of the broad part. Another board about  $\frac{3}{4}$  in. thick (fig. 5) has shallow strips at each corner on the top side, into which the bottom of the camera will fit tightly.

Both camera and its carrier board will then slide freely between the flanges of the baseboard, and after connection with a velvet tube may be secured in position by the thumbscrew. The short body tube T, previously mentioned, which may be bought of any working optician for a few shillings, is fitted into a block of wood (fig. 3), and both this and the object carrier (fig. 2) are placed between the guide bars on the top of the turntable V (fig. 4).

A narrow strip of sheet metal bent into the form of a letter L, and having a screw F (fig. 3), makes the fine adjustment, and the coarse adjustment is done by sliding the object carrier (fig. 2).



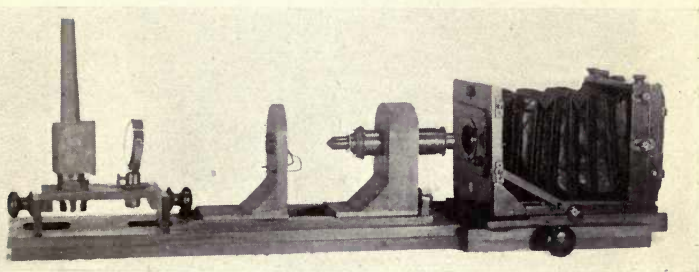


FIG. 1.  
Simple microscopic outfit.



It will be noticed that in fig. 2 a short tube A is shown, though such is not necessary for ordinary low power work ; but it is a decided advantage to be able to use accessories, such as iris diaphragm, polariscope, spot lens, and substage condenser, all

FIG. 2.

FIG. 3.

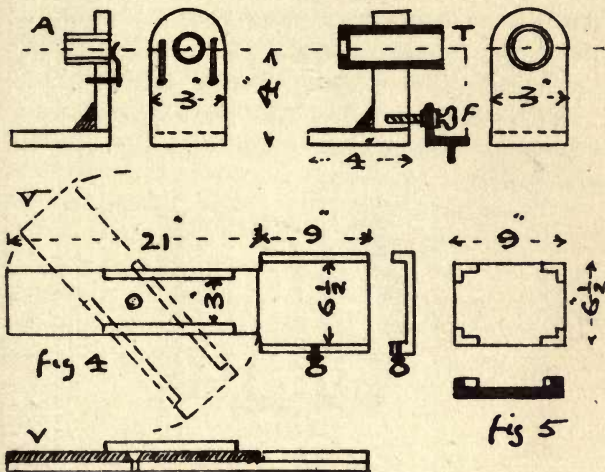


FIG. 6.

DETAILS OF SIMPLE MICROSCOPIC OUTFIT.

of which may be slipped into this tube, thereby extending the field of operations considerably. Such a tube is known as an adapter, and may be purchased of most microscope makers for a nominal sum ; the additional fittings for it, of course, may be added when desired.

The centres of camera, body tube, and hole in object carrier must be accurately in line, so that no after adjustments will be needed. When not in use the whole thing is so light that it can be lifted with one hand, and stowed away on a cupboard shelf until it is wanted again, and its portable form enables one to carry it from town to town for purposes of practical demonstration with less inconvenience than carrying a box of lantern slides.

It will be understood that the remarks about cost apply only to the framework, and not to accessories.

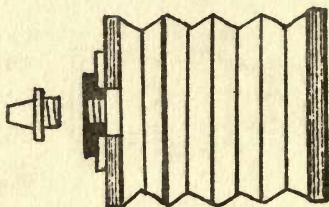


FIG. 7.

#### LENS ADAPTER FOR CAMERA.

For taking photographs of large objects, such as whole insects, no microscope is required. Instead, an adapter for the camera is employed. This is merely a ring of brass with screw thread on its outside to fit the quarter-plate camera in place of the usual photographic lens, and it has a threaded hole in the centre to receive any low



power microscopic objective, as shown in fig. 7. A Davis shutter, or small iris diaphragm, to "stop down" will be helpful in controlling the depth of focus, and getting sharper outlines than would be possible with a larger aperture.

Special lenses may now be obtained to be used without eyepiece, which are very suitable for photographing large specimens.

Watson's "Holostigmatic" lens has an iris diaphragm and standard gauge thread to fit any ordinary microscope, or it may be used in the adapter at the end of camera, as just described. It gives splendid definition, has a rapidity of  $f/6$ , and a large flat and uniformly sharp field free from distortion. The diaphragm opening, corresponding to a circle of confusion of .003in. for various magnifications, is stated to be as follows:

| Stop.  |                   | Magnification. |
|--------|-------------------|----------------|
| $f/45$ | is sufficient for | $\times 2$     |
| $f/32$ | " "               | $\times 4$     |
| $f/22$ | " "               | $\times 6$     |
| $f/16$ | " "               | $\times 8$     |
| $f/11$ | " "               | $\times 12$    |
| $f/8$  | " "               | $\times 18$    |
| $f/6$  | " "               | $\times 24$    |

In most cases the best results will be obtained by using the diaphragm opening given in this list, but it may sometimes be advisable for a thick object to use a smaller one to get the required depth of focus.

With a long tube microscope the field of view is limited to a comparatively small area, and it would be found difficult to see in one view even the whole of such a small coin as a threepenny bit, whereas by means of the adapter a five-shilling piece could be covered and photographed. The watch face (fig. 8), real size of dial 1 $\frac{1}{2}$ in. diameter, was taken to show the covering power of a 3in. objective.

TO TAKE A PHOTOGRAPH SAME SIZE AS OBJECT  
WITH AN ORDINARY PHOTOGRAPHIC LENS.

Extend the camera so that the ground-glass screen from the focal centre of lens shall be twice the focus of lens, whatever that may happen to be, and put the object to be photographed at exactly the same distance in front of the lens.

The distance, therefore, between object and image will be four times the focus, with lens in centre.

For example, suppose focus of lens be 5 $\frac{1}{2}$ in., the image would be 11in. behind the lens, and the object 11in. in front. Butterflies, spiders, shells, and similar large objects of considerable thickness may be photographed real size in this way better than with a microscopic objective. Dallmeyer's Stigmatic lens, Series II., gives excellent results.

For photographing natural history specimens in water, such as caddis worms, beetles, or tad-

poles, it will be desirable to have a tilting table whereby the camera can be used vertically. A convenient form to fit on top of a tripod is sold by dealers, but a handy man can readily fit up a couple of hinged boards with means of securing them at right angles. The vertical board, of course, has a screw for taking the camera, and the horizontal board may be secured to the edge of a table, or be attached in the usual way to the top of

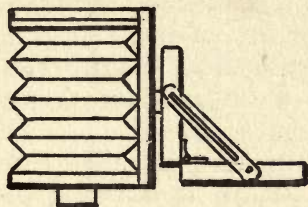


FIG. 27.

TILTING BOARDS FOR CAMERA IN A VERTICAL POSITION.

A very convenient form of vertical camera, which turns aside to facilitate adjustments of the microscope, is supplied by Swift and Son. Some other makers offer a camera bench designed for use in either vertical or horizontal positions.

the tripod. A glass tank placed underneath the lens allows easy illumination of the object, and permits regulation of the light either through the bottom or sides by means of plain mirrors. For living objects in motion the exposure must be instantaneous, and sunshine or flashlight may be enlisted for this purpose.

## CHAPTER IV.

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### PHOTO-MICROGRAPHY WITHOUT A MICROSCOPE.— APPARATUS FOR THE WORK.—REFLECTED LIGHT FOR OPAQUE OBJECTS. — DOUBLE LIGHTING.

With such a baseboard at disposal as that just described, or its equivalent, let us now take a quarter-plate camera from which the photographic lens has been removed, and go step by step through the movements required for making our first picture without a microscope. Neither the short body tube (fig. 3) nor its standard will be required for this purpose.

First place the adapter and a 3in. objective in the brass mount on the front end of camera. Now put the camera on the wood receiving block (fig. 5), fasten it with the thumbscrew, select a suitable slide, say a small transparent insect, for the object carrier (fig. 2), and put it in line facing the lens, with sufficient room for free movement to or from the camera during focussing, for in this case the specimen is to be moved and not the camera.

Almost any kind of lamp will do for lighting the object if the bull's-eye be placed to collect and emit the rays of light properly ; but the importance of efficient illumination is so great that the reader



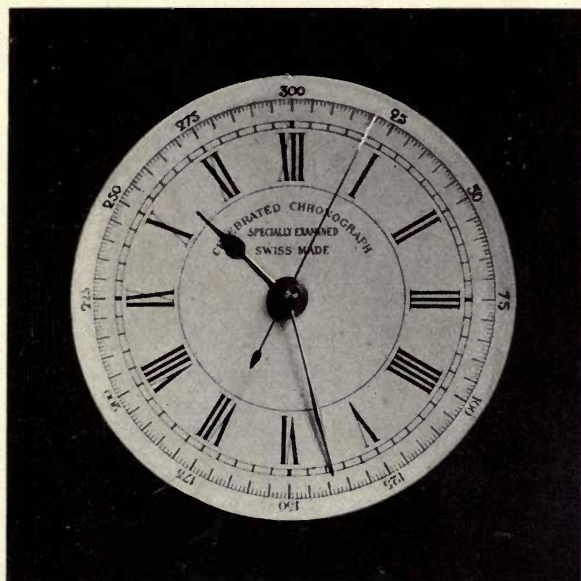
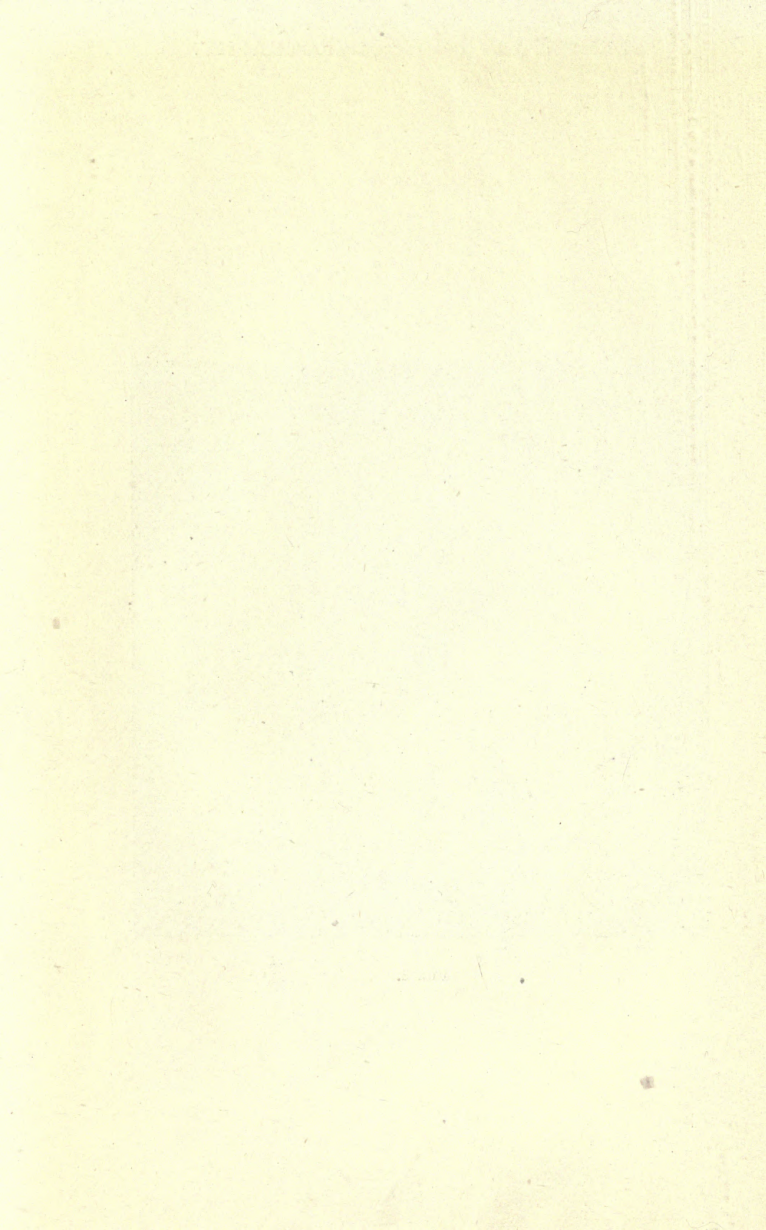


FIG. 8.



should study the use of the bull's-eye, as described in the next chapter. This will save repetition here, and probably the mistake too often made by beginners in supposing a powerful light to be all sufficient for getting a good negative.

On the contrary, it is not so much the brilliancy of the illumination as its right application that makes it effective.

Even a common nightlight in the hands of an expert might yield better results than acetylene gas at the service of a novice.

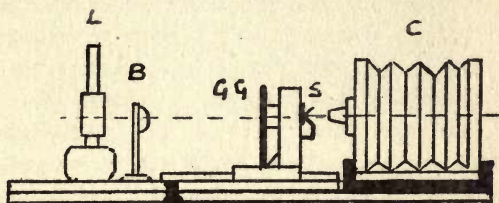


FIG. 9.

C, Camera. S, Specimen. G G, Ground-glass. B, Bull's-eye.  
L, Lamp.

The camera, specimen-holder, and lamp should now be as shown in fig. 9, with all centres in one line.

Having focussed the object sharply by means of a focussing glass—the naked eye being quite unable to discern the point of best definition—and interposed a piece of ground-glass between lamp and object to distribute the light and give even

illumination of the field, we are ready for the exposure. At present we need not be concerned about the amount of magnification.

A cap placed on the lens, or a piece of black cardboard reared in front of it, will exclude light from the camera while the shutter of dark slide is withdrawn.

Dealers supply a sliding shutter mounted in a nosepiece to fit between the objective and the microscope body at about 7s. 6d.

When everything is in readiness, remove the cap, or cardboard, and expose for as many seconds or minutes as may be necessary, for which information read the chapter on exposure. Again cap the lens, or replace the cardboard, and close the dark slide, and the plate is ready for development. Slow plates of almost any brand will do for a start.

If any difficulty be experienced in getting even lighting over a large field, it may be instantly overcome by using a lantern instead of the oil lamp and bull's-eye; first removing the projection lenses, and leaving only the large inner condenser for illumination purposes.

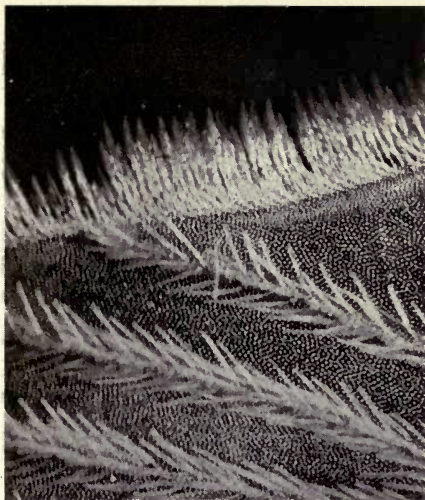
#### REFLECTED LIGHT FOR OPAQUE OBJECTS.

With a transparent object like that last described, it will be remembered the light was sent through it from the back, but when the object is opaque this cannot be done, consequently another

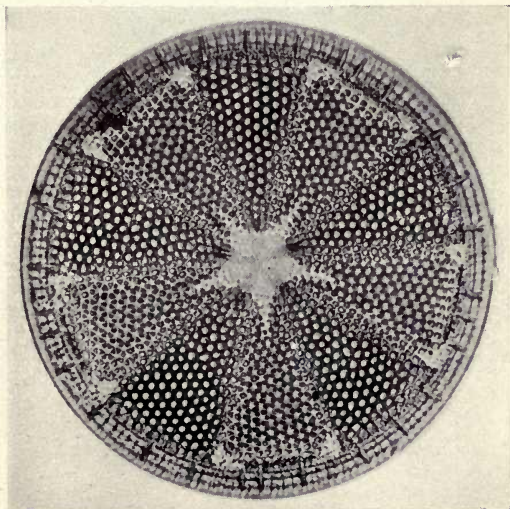


ELEMENTARY PHOTO-MICROGRAPHY.  
PLATE III.

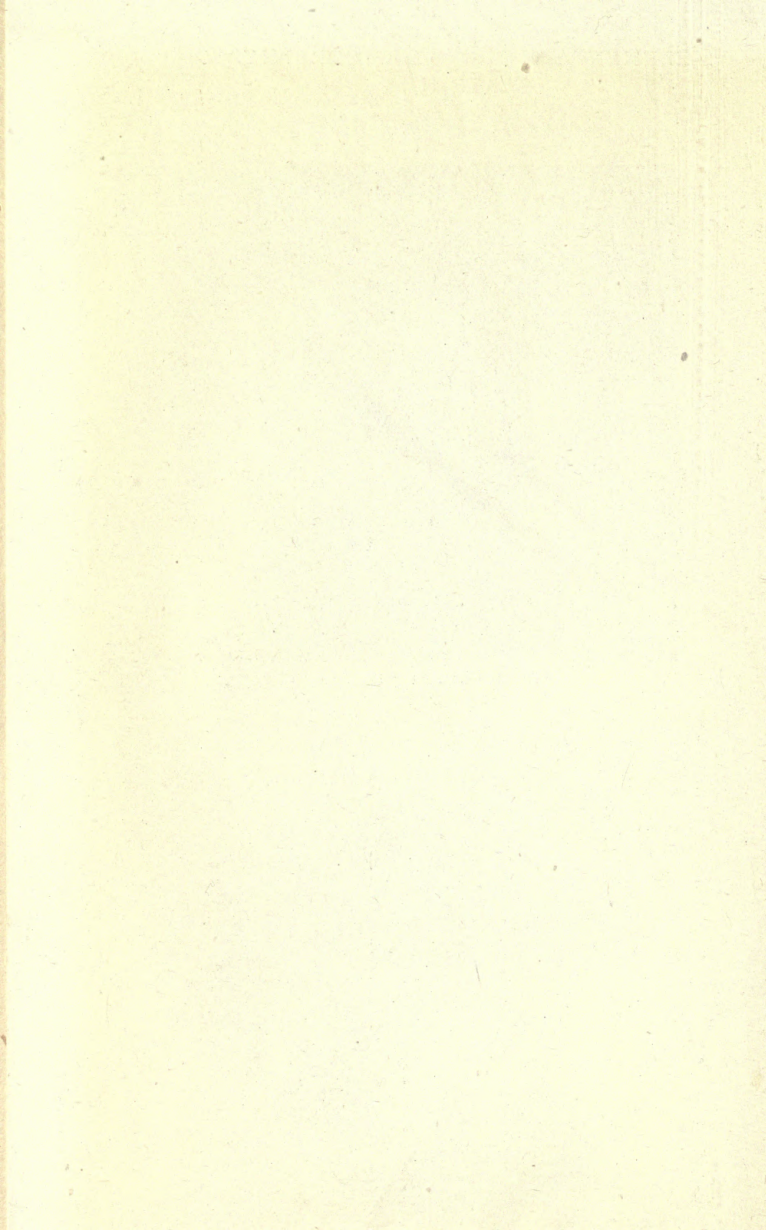
TAKEN BY DIRECT LIGHT.



Wing of Gnat.  $\times 70$ .



Heliopelta.  $\times 200$ .



method is adopted, viz., lighting from the front instead of the back.

Both stronger light and longer exposure will now be needed, especially when object is of dark colour, for only that portion of light which is reflected can act upon the dry plate. A lamp and bull's-eye will do very well, but an incandescent lantern is better still. This is effective and clean, and is got ready with little trouble. It also reduces exposure. A rubber tube connected with nearest gas bracket enables the light to be turned on or off when required. This will illuminate large areas in a most satisfactory way, and with less trouble than a lamp; but the projection lenses must be taken away and the inner 4in. condenser alone used.

In fig. 10 it will be noticed that the convex side of bull's-eye is turned towards the lantern. The best angle for the light to be thrown upon the slide will be found by experiment. This may be at one time at right angles with centre line of camera, or at another time more as shown in fig. 10.

For small objects, a silver side reflector of parabolic form will take the rays of light from a lamp and distribute them over the object; but unless rightly done, one side of object will be sharp and the opposite side fuzzy, owing to deficient lighting; in other words, one side would be well lighted and the other in shadow.

With opaque objects under reflected light it is sometimes difficult to avoid reflection from the cover glass; uncovered objects, therefore, should be used where possible.

The side reflector is, of course, placed not on same side as lamp, but at the opposite side of stage. The light will consequently pass in front of the object, to be reflected back again on to the specimen in an intensified form.

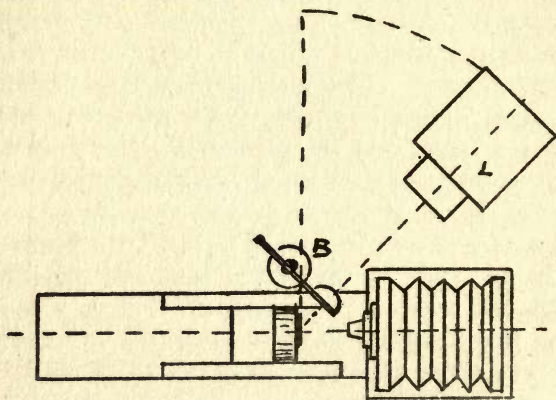


FIG. 10.—PLAN.

L, Lantern. B, Bull's-eye.

Some photographers light the specimen from both sides, though as a rule this is unnecessary. A small mirror, however, to reflect the light on to the side of object furthest away from the light will at all times be advantageous in preventing too deep shadows.



The use of two lamps for lighting an object from opposite sides is not to be confounded with the "double lighting" where two different modes of illumination are employed. This refers rather to transmitted light for lighting up the field or background, and reflected light for illumination of the object itself. Such a combination gives results different from those yielded when only one kind of lighting is used, and the effect is modified according as one or other of the lights predominates.

Pleasing varieties of pictures of great delicacy may also be obtained by putting a  $3 \times 1$  in. slip of ground-glass, or white porcelain, on the stage, underneath the object when this is mounted on clear glass.

In the method of double lighting, the direct light from behind the specimen will prevent over intense shadows from the reflected or side light: a fault met with in some photographs of thick objects mounted on opaque light-coloured ground and exposed only to one source of light.

## CHAPTER V.

### THE MICROSCOPE AND ACCESSORIES.

THE MICROSCOPE.—ITS ESSENTIALS.—A SIMPLE BASEBOARD.—THE FOCUSSING GLASS.—COMBINED LAMP AND BULL'S-EYE.—LAMP ADJUSTMENTS.—MAGNESIUM RIBBON.

A good second-hand microscope may often be purchased at less than half its original cost. Cheap microscopes by unknown makers are useless for photography, therefore it is better to get a good one second-hand than a poor one new. In selecting such a one the following points are desirable :

The maker should be one of good repute.

English pattern recommended.

The body tube should be preferably of short length with full-size eyepiece and coated dead black inside.

Rackwork draw tube to give 10 in. when extended.

One advantage of an adjustable tube length is that it allows the use of objectives, which may be corrected for either short tube or long tube.

It should have—

A rack and pinion substage motion for adjustment of the condenser with a centring arrangement ;

An iris diaphragm and disc plate ;  
A mechanical stage ; and  
A coarse and fine adjustment.

The advantage of a short tube is seen in the much larger field when using low powers. If the microscope have a polariscope attachment, all the better, but this is not essential.

It should have two eyepieces, A and C, and a battery of good objectives, say, to begin with, 3in., 2in., 1in.,  $\frac{1}{2}$ in., to which may be added afterwards  $\frac{1}{8}$ in. and  $\frac{1}{12}$ in. oil immersion, as the reader feels his way to use higher powers. All these should be kept free from dust and carefully cleaned with washleather before use. The washleather should be kept in a stoppered jar and used only for this special purpose. Cleanliness throughout is of the highest importance. A mere dust over with a pocket handkerchief is not sufficient. The mounted object to be photographed should also be rubbed back and front, for it is astonishing how readily dust and hairs adhere, and it must be examined with the focussing glass before one can be satisfied that it is clean. Due attention must also be given to the eyepiece, because any specks of dirt left thereon will inevitably appear in the form of pin-holes or patches on the negative.

Caution when touching the oil lamp not to grease the fingers is advisable. A short black velvet

tube to fit over the eyepiece will be required to connect the microscope with the opening in the quarter-plate camera, the lens having been removed, as it is not required when using the microscope. A small iris diaphragm called a Davis shutter will be found useful for getting better penetration and definition. This screws into the body tube of the microscope at one end, and receives the objective at the other end. It removes any halo or glare, and enables a sharp picture to be taken. For feathers, eggs of insects, and polycystina it is almost indispensable.

#### BASEBOARD FOR USE WITH AN ORDINARY MICROSCOPE.

A carpenter may be got to construct a simple baseboard, on which the lamp, microscope, and camera may be placed. At one end of the board two flanges are fastened, between which a block bearing the camera on the top slides freely to and from the microscope. This sliding block, again, has flanges to receive the small camera and keep it rigidly in position whilst drawing the dark slide. Two thumbscrews in one flange of the baseboard will fix the sliding block, and will secure both block and camera after connection with the microscope by means of a velvet tube has been made.

Note that the bellows of the camera must be capable of full extension when placed in the recess



on the top of the block. Thus enlargement may be regulated by racking the bellows in or out without disturbing the connections. A reference to the sketch (fig. 13) will make this clear.

Fig. 11 is a board about 5ft. long, 8in. wide, and 1in. thick. Fig. 12 is the end view showing flanges, say, 1in. deep. The sliding block (fig. 13) slides freely between these flanges, and is fixed by the thumbscrews. The camera, microscope, and lamp are seen in position in fig. 14.

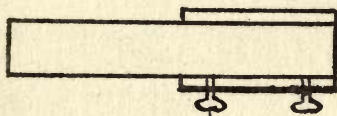


FIG. 11.



FIG. 12.

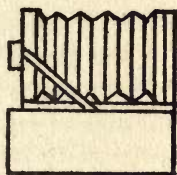


FIG. 13.

For a focussing glass any of the ordinary type will do, and when once set to suit the sight of the owner, will need no further alteration. A mark with lead pencil must be made on the rough side of the ground-glass screen, and then, turning it over, the focussing glass is put in contact with the smooth side, the lens being screwed to and fro until the pencil mark is clearly in focus. It is important to rest the foot of focussing tube upon the glass whilst making the adjustment. The focussing glass may then be slid over every part of

the screen, after the projected image is thrown upon it, to ascertain whether each part of the object is equally in focus.

When high powers of the microscope are employed, the rough side of the glass should have a few places about the size of a shilling rubbed with glycerine to render them transparent, whereby the focussing of delicate fibres is found much more certain. One should be put in each corner and one in the centre.

#### COMBINED LAMP AND BULL'S-EYE.

The paraffin lamp and auxiliary condenser are better mounted on one stand than when separate. When used separately, the adjustments have to be made every time, whereas when the lamp and condensing lens are capable of being moved about together without disturbing their relative position, one setting is sufficient.

In photo-micrography success will not be obtained without proper illumination, so that the importance of first setting the bull's-eye in its right place cannot be over-estimated.

A lamp which sheds its light in every direction would at best give only a feeble image in the camera unless the scattered rays were collected and directed by a lens towards the microscope. Now, by using the bull's-eye, which is merely a plano-convex lens, as a condenser, we may get the best

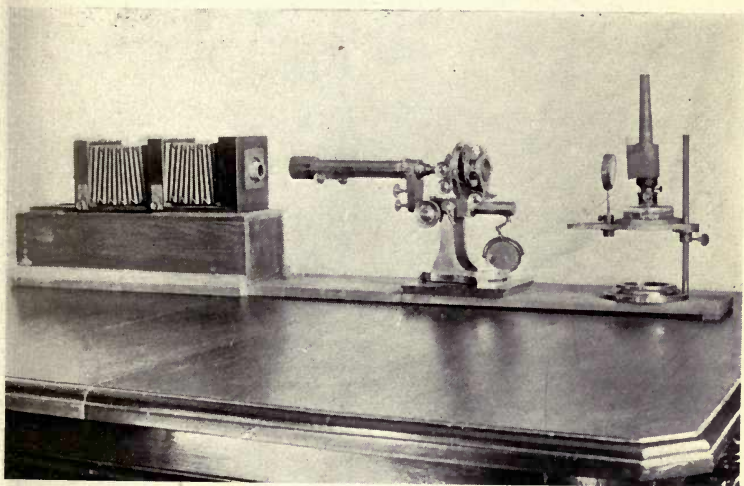


Fig. 14.





and most brilliant effects from the light at our disposal, though even then the direction of the light passing through the bull's-eye is all-important. A very small movement of the combined lamp and bull's-eye has been known to reduce the exposure one-half, because the rays of light had not previously been concentric with the axis of the microscope.

Several good lamps with bull's-eye attached can be bought, but an equally efficient arrangement may be made, as shown in sketch (fig. 15).

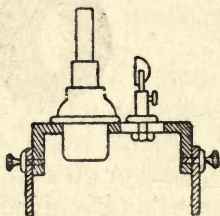


FIG. 14.



FIG. 15.

Fig. 15 shows a simple wood frame having a circular hole for a paraffin lamp, and a slot in which a tube carrying the bull's-eye may slide to and from the lamp. The two end supports are free to rise and fall, and are secured with screws when the centre of the flame is brought to the height of centre of microscope.

A metal chimney is preferable to glass, but if clear glass, then a shade with an opening on one side to drop over the tube is desirable.

## LAMP ADJUSTMENTS.

To set the lamp properly, the flame is first turned gradually up to its working height, and put with the edge of the flame (not the flat) towards the condenser. The flat side of the bull's-eye is put next the flame, at its proper focal distance, and with centre of lens at same height as centre of flame. Having done this, the photographer's next step is to look right into the lens through a pair of



FIG. 16.



FIG. 17.

neutral tint spectacles, and to raise or lower the flame until the whole area is brilliantly illuminated. If dark spots appear in the lens, it is moved towards or from the flame to get a bright disc of light. If this does not give the desired result, raising or lowering the lens must be tried. When the bull's-eye is too near the flame it will show dark patches with bright line in the middle, as fig. 16, and when too far away it will appear as fig. 17.

If focussed but not centred, a crescent of light will show at one side of the bull's-eye. A little experimenting will soon give the correct position, and when once this is determined, make a mark on

the bull's-eye spindle, so that it can be removed and replaced in exactly the same position, to facilitate the occasional use of the lamp flame without any bull's-eye. For instance, in getting "critical light," after the objective has been focussed on the slide, an image of the edge of lamp flame must also be focussed through the substage condenser on the object to be photographed, and to do this the bull's-eye is taken away, but is afterwards interposed when the edge of the flame has been shown as a streak of light in the centre of field.

A plano-convex lens should be so placed that parallel rays either enter the convex surface or emerge from it, and its focus is approximately the diameter of curvature, or twice the radius of its convex surface.

One advantage of an oil lamp is the absence of that intense heat which gives the user of limelight so much trouble.

When electric current is obtainable, the Nernst lamp is very handy and efficient, or with a gas supply the incandescent mantle can be usefully employed. Both these lights reduce the exposure considerably.

#### MAGNESIUM.

Magnesium ribbon burns at the rate of about 2ft. per minute. It is purchased in coils, and can

be fed through a tube, though the smoke from this is objectionable in ordinary households, where it is presumed the reader will usually work.

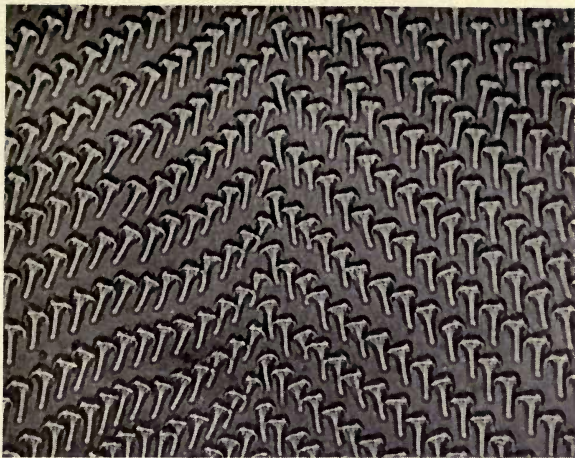
If care be taken to get uniform illumination by means of ground-glass, then much time is saved by this light, which is rich in actinic rays, but the beginner is not advised to try it until he has a good knowledge of all the points to be observed in the taking of a perfect negative. When using very oblique illumination, an exposure of two or three minutes with magnesium will be found equal to sixty minutes with paraffin lamp, and with high powers the shorter the exposure the better. With very long exposures through an oil-immersion objective there is a danger that the focus will be altered by a variation of the temperature of the room, for even a change of a few degrees may be fatal to the stability of the image.



ELEMENTARY PHOTO-MICROGRAPHY.

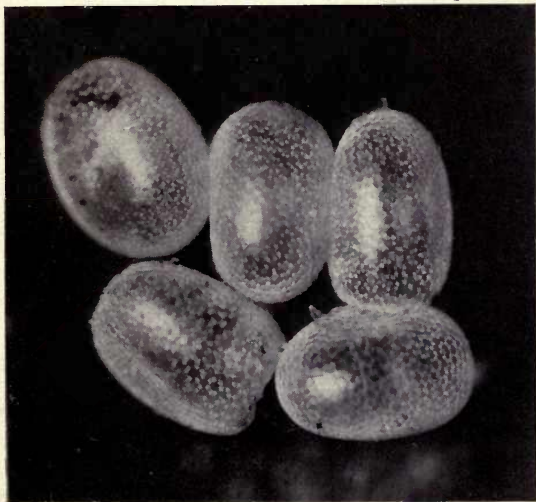
PLATE IV.

TRANSMITTED LIGHT.



Radula of *Achatinella*.  $\times 180$ .  
Showing teeth in "tongue" of snail.

REFLECTED LIGHT.



Eggs of Magpie Moth.  $\times 25$ .



## CHAPTER VI.

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### ILLUMINATION.

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ILLUMINATION. — ADVANTAGES OF ARTIFICIAL LIGHT.—A SIMPLE OBJECT WITH A LOW POWER.—CONNECTING TUBE FOR CAMERA.—DARK-GROUND EFFECTS.—RIGHT USE OF CONDENSER. — OBLIQUE ILLUMINATION. — MULTIPLE COLOUR ILLUMINATION.

In the matter of illumination, the landscape photographer is at a distinct disadvantage when compared with workers in other branches of photography, for he has absolutely no control over the lighting of his subject. True, he can select the time of year and the time of day most likely to yield any desired pictorial effect; but he must be a man of leisure if able to avail himself of every fitting occasion; and even then, if the scene of his operations be at any distance, probably by the time he arrives at his destination, the climatic conditions may be completely changed.

The selection of light and shade equally with the choice of point of view makes all the difference between one photographer and another. The one with knowledge, taste, and opportunity gets probably on every occasion a real picture, whilst a snap-shotter in the ordinary way gets merely a



photograph of some kind. Portraiture by daylight, however, in a well equipped studio, gives the operator a chance to model his sitter as he pleases, and in this respect the conditions follow more closely those under which a photo-micrographer works when using artificial illumination.

Photography through the microscope, of course, can be done by daylight by means of a heliostat ; and, indeed, some of the best known American workers achieved most successful results when using this instrument ; but it is only suitable for a specialist, and not to be recommended for ordinary use. Apart, then, from sunlight, there are many other sources of illumination, most of which are efficient for all purposes.

Artificial light has the decided advantage of being more constant than daylight, from which it follows that exact exposures may be repeated successfully as often as required. Probably for mere visual inspection of an object, almost any kind of light will do, though even for this purpose the best effect cannot be got unless certain conditions are fulfilled. Defects not so readily observable by the naked eye are accentuated and made clearly visible on a photographic plate, so that the art of illuminating an object properly is one that must be learned before one can hope to secure good negatives. The risk of failure may certainly be reduced to a minimum, if only thorough



ELEMENTARY PHOTO-MICROGRAPHY.  
PLATE V.

TAKEN BY REFLECTED LIGHT.



Eggs of Parasite on Feather of Pheasant.  $\times 24$ .



Pollen of Mallow.  $\times 75$ .



familiarity of one special illuminant be acquired, and results be tabulated for ready reference.

The man who is always changing his methods is not as a rule either able to satisfy himself or to produce a creditable output; therefore, it is not advisable to try every kind of light and every brand of plates or paper before settling down to steady work.

In selecting a radiant, the chief thing to be considered is that the light shall be steady and of the same illuminating effect at all times. The length of exposure may be shortened or lengthened by using a more or less intense light, always remembering that the more intense the light the more the trouble from heat and other dangers.

Theoretically the source of light should be a mere point, and consequently of great brilliancy; but for very transparent objects a less luminous source is even an advantage. Bearing these conditions in mind, the reader may decide according to the circumstances of his environment which lamp to adopt. If electricity be available, this offers everything necessary. Limelight is good but troublesome. Acetylene gas is easily worked and satisfactory. Incandescent gas or a well-made incandescent spirit lamp with inverted mantle is convenient and powerful.

Magnesium wire answers well for short exposures, and instantaneous photographs may be

taken by flashlight. Authorities differ very widely about paraffin oil. Some condemn it altogether ; but in the writer's opinion a good oil lamp is the most convenient and best for anyone who has to work at intermittent and irregular times. It can be started at any moment without preparation, and will perform excellently whether high powers or low powers be employed. In fact, negatives from the most difficult test objects can be secured that will compare favourably with those taken by any of the lamps previously named.

Assuming that preference is shown for one of the lamps just named, the next desirable thing is to use it under different conditions. So many people fail to take advantage of the varied methods of illuminating an object under view that much of the usefulness of a microscope is lost, and the owner fails to grasp the immense possibilities of other systems than the one to which he confines himself. For instance, take a simple transparent crystal with polarising properties, and view it under direct or transmitted light. Its configuration is certainly visible, but no adequate conception of its inherent beauty can be got from such inspection. Now add a polariscope to the microscope, and what was merely as uninteresting as a piece of plain glass becomes arrayed in gorgeous colours, ever varying in beauty as the prism is rotated on its axis. Parts are differentiated in



brilliant tints that before were absolutely invisible. Next try the crystal with dark-ground illumination. Here again it presents a fascinating sight like a flashing jewel on black velvet. Either a spot lens or a central stop in the condenser may be used for the purpose, or even swinging the mirror to one side and throwing oblique light will give the effect. Further, the object may be put under reflected light, when again it presents a totally different appearance.

Next a combination of reflected light and transmitted light may be tried, which will have the effect of making the crystal stand out in relief, and offer noteworthy points. After all these, the microscopist is not at the end of his resources. He may then insert colour discs in the condenser, and have the crystal one colour with a background of any other colour he pleases.

Of course, not every object will allow of every kind of lighting, but most will stand two or three.

Other advantages probably may be obtained by the use of colour screens or light filters. From the foregoing remarks, then, it will be gathered that the landscape photographer has no power to alter the prevailing light and shade, whilst the photo-micrographer can modify them at pleasure. But, on the other hand, the latter will find difficulty in getting any contrast at all when dealing with very transparent objects, and it is here that

his individuality will be manifested. The iris diaphragm will sometimes be needed; at other times it may be the polariscope, especially for crystals, or perhaps the colour screen must be employed. Which method and which colour screen will only rightly be selected after experience has been gained. If the worker prepares his own object, he can often stain it to bring out its details. However, all these matters will have to be dealt with separately.

Commencing with a simple object and the lowest power, we first set up the baseboard, with lamp, microscope, and camera duly placed in position (see fig. 14), but as an object may be photographed by direct transmitted light, reflected light, and with dark ground or light ground, we will first consider transmitted light and a light background.

If the reader has tried the simple experiment of getting an enlarged picture on a sheet of white cardboard, as described in Chapter II., he will have no difficulty in obtaining the image on the ground-glass screen of the camera.

Having placed the object on the stage of the microscope, it is focussed with the A eyepiece, the camera and sliding block having been removed for this purpose. No substage condenser is needed for powers lower than  $\times 100$ , but for higher powers it is indispensable; therefore, instead of critical

light used for high powers, we take parallel rays from the bull's-eye after the paraffin lamp has been set according to the instructions previously given. The eyepiece is next taken out and a piece of white cardboard placed about 12 in. away from the end of the body tube to act as the screen, and receive a projected image from the microscope. The disc of light will possibly be found brighter in one part than another. The lamp is moved sideways until the whole disc is equally illuminated, with the object well defined in the centre. The focussing may be altered for this purpose. The eyepiece is replaced to see if the field be still uniformly lighted, a slight adjustment of focus again being necessary. If the lamp be in the right position, the disc of light will be sharp and uniform right up to the edge of the circle with or without an eyepiece. The cardboard is taken away, and the camera brought up to the microscope, with the velvet connecting tube over the eyepiece.

This tube may be made of cardboard lined with black velvet. It should slip over the eyepiece, and project about an inch. A short tube, say  $\frac{3}{4}$  in. long, should also be placed in the brass mount of camera that usually carries the lens, and its diameter must be a  $\frac{1}{4}$  in. less than inside of the eyepiece tube, so that when the camera is slid up to the microscope, a light-tight

connection is assured without danger of disturbing adjustments.

A reference to sketch will make this clear.

The sliding block is secured by the thumb-screws, and the figure which will now appear on the ground-glass at the end of camera is examined.

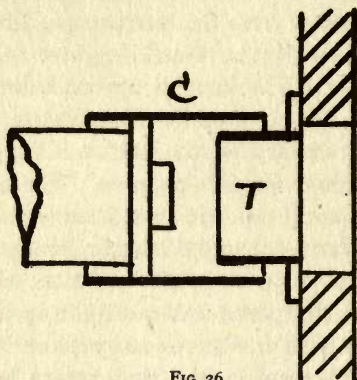


FIG. 26.

C, Cardboard tube. T, Camera tube.

If the magnification be too small, the camera is racked out ; or if too big, closed.

The object is centred by means of the mechanical stage. If size and position are correct, fine focussing may be performed with focussing glass through the transparent places at each corner and in the centre of screen.

Perhaps the object will be too brilliantly lighted and the whole be drowned in a flood of light. If so,

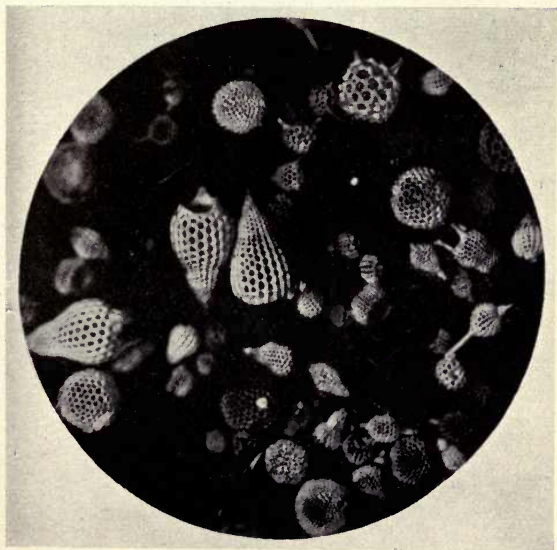


ELEMENTARY PHOTO-MICROGRAPHY.  
PLATE VI.

TAKEN BY REFLECTED LIGHT.



Foraminifera.  $\times 40$ .



Polycystina.  $\times 45$ .



the iris diaphragm is closed a little ; not too much, or diffraction effects will result, the aim being to increase contrast by securing dark outlines on a light screen.

Naturally the condenser is the proper place for reducing the angle of the cone of light, but both the Davis shutter and the iris diaphragm will be useful for getting contrast of the object with its background. When this is secured, the dark slide may be inserted and an exposure made.

#### DARK BACKGROUNDS.

It is possible to light an object by rays thrown at such an acute angle from one or more sides that none of the direct light enters the objective. This is known as dark ground illumination. For examination purposes the light may be reflected from the mirror drawn to one side, but for photography the object should be lit up from a hollow cone of light, which diverges after passing the focal point on the slide.

Objects such as polycystina and diatoms show much better as light figures on a black ground. To obtain this effect the substage condenser and diaphragm plate will be needed. Let them, therefore, be attached, and the microscope focussed on the object as before. Now take away the bull's-eye, and with substage condenser focus the edge

of flame on the object, which will give the best possible illumination for examination purposes, though too small in area for low power photography. This is termed "critical light." We must therefore find some means of diffusing it over the whole surface of the object, and this can be done by again interposing the bull's-eye, when an evenly-lit disc on the cardboard is sought as in the method last described. Having got it satisfactorily, the central rays are stopped out by means of a disc or stop in the diaphragm plate, so that an annular ring of light only enters the condenser.

If no suitable condenser be at hand, a bull's-eye may be requisitioned and made to do good service, especially for large objects. Paste on it a piece of black paper to block out the central rays, and use it in place of a condenser (fig. 18). A spot lens or a Wenham parabolic reflector to fit the substage will also give a dark ground with the object illuminated thereon.

For living bacteria, etc., several kinds of illuminators in the form of condensers or paraboloids are now in the market for obtaining dark ground with high powers. These are oiled to the under-side of object slide, and direct the light in such a way that no direct rays enter the microscope. The object thus appears luminous with dark surroundings.



After proper adjustments, if it be diatoms we are photographing, they will now be seen glittering like pearls upon black velvet. The microscope is connected up with camera, re-focussed, and an exposure made. Longer exposure must be given than with direct light. The mirror of the microscope is not required. It is well to make sure that the substage condenser is properly centred with the optical axis of the microscope before commencing, for unless the two

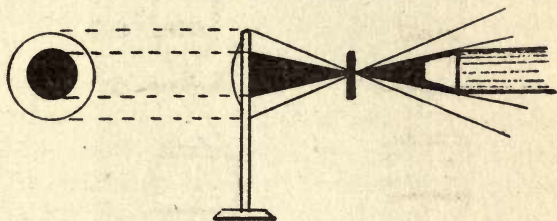


FIG. 18.

coincide, the condenser, when sending forth its beam of light, will be like a rifleman aiming at a target but not at the bull's-eye, and consequently the best effect will not be obtained. Moreover, not only must the condenser be correctly centred, but exactly focussed as well, otherwise the rays of light which illuminate the object will not all enter the microscope, but some will diverge in a cone outside of it, and as it is only from the image forming rays passing through the microscope that

a picture can be obtained, a considerable loss must ensue with wrong adjustments.

This will be made clear from diagrams (figs. 19 and 20).

When the condenser is stopped down by the iris diaphragm, or otherwise made to correspond with the aperture of objective used, and both condenser

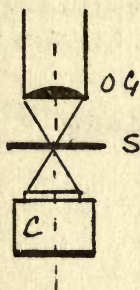


FIG. 19.

Objective and condenser correctly  
focussed and centred.

O G, Objective. S, Slide. C, Condenser.

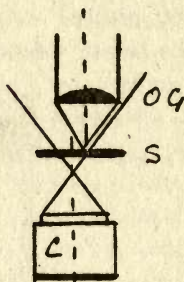


FIG. 20.

Condenser not focussed  
and not centred.

and objective are focussed on the object itself, the best possible definition and illumination will be got. But when the condenser is out of centre and out of focus, the rays of light will be dispersed uselessly, as seen in fig. 20.

Some negatives that yield prints on a light ground may also be used for printing with a black

ELEMENTARY PHOTO-MICROGRAPHY.  
PLATE VII.

231-4

TAKEN BY REFLECTED LIGHT.



Eggs of Parasite of Peacock.  $\times 30$ .





ground by simply making a positive from such a one and using this to print from.

Fig. 21 (Plate VIII.) is a light ground print from a negative taken without any central stop in the condenser, and fig. 22 is a print from the glass positive which gives the dark ground effect.

When photographing without the eyepiece, a bright spot in the centre of the illuminated disc will appear if the body tube be not lined with black velvet or otherwise dead blacked. This is caused by reflection, and is specially noticeable when using polarised light, but the eyepiece removes this defect entirely, though with greatly prolonged exposure.

Occasionally the substage condenser may be lowered with advantage, and a more even illumination secured, although at a sacrifice of brightness. When the markings of certain diatoms are to be seen at their best, the light should be thrown on them obliquely by means of a crescent-shaped diaphragm, taking care that the lighting of the ground-glass screen is both uniform and sufficient to ensure a background of tolerable density.

Oblique light, although very good for visual inspection, is ill-adapted for photography, and without great care will result in a blank negative, even after long exposure. False images are also created by oblique light, which introduces sources

of error only detected by an experienced microscopist.

The writer has never found the Lieberkuhn of any advantage in illuminating opaque objects. A reflector called a vertical illuminator may be tried when the lens approaches so near to the object that it is difficult to project a beam of light from the side reflector. It is especially useful for photographing metals with high powers or objects mounted dry on cover.

#### MULTIPLE COLOUR ILLUMINATION.

A method of multiple colour illumination has been devised by Mr. Rheinberg, by which it is possible to cause an object and its background to appear of different colours in a striking manner, and so secure a greater contrast than usual. Illustrations and particulars of this method are given in the "Illustrated Annual of Microscopy" for 1898. Briefly stated, it consists of very thin sheet gelatine of various colours cut into annular rings and central discs to fit the stop holder of condenser exactly as when dark-ground illumination is employed, and such as any amateur could easily cut out for himself. In other words, the circular disc has a hole punched through its centre, which is then filled up by a piece of a different colour as if a threepenny-piece were placed on a halfpenny, the copper being, of course, removed from under

neath the silver coin. The central spot, which gives colour to the background, should be rather darker than the ring outside it. The result of a red ring with a blue centre would be a red object on a blue background. Without doubt the method is well adapted for the study of living organisms and diatom structure as well as for photography.

Pleasing effects are obtainable by dividing the outer annular ring into quarters, with two opposite sections of one colour—top and bottom say red, and the other two (right and left) green with a black spot in the centre. Such a combination would make the texture of silk cloth mounted in Canada balsam appear as if the warp were one colour and the weft another.

Mr. Rheinberg recommends blue or green for the central spot rather than red or orange, and says that a green centre with red periphery will give superior results to a red spot and green periphery.

For resolution of diatom structure a blue periphery and a small clear centre are the most advantageous.

## CHAPTER VII.

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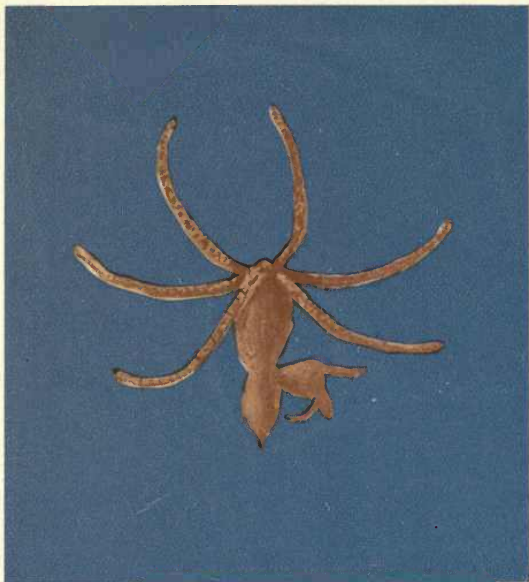
FOCUSSING SCREENS.—FINE FOCUSSING WITH HIGH POWERS.—TRYING EFFECTS.—OIL IMMERSION LENSES.—TEST OBJECTS.—DIATOMS AS A HOBBY.—MEASURING THE AMPLIFICATION WITH ANY EXTENSION OF CAMERA.—TABLE OF APERTURES AND MAGNIFYING POWERS OF OBJECTIVES WITH EYEPIECES.—THE POLARISCOPE.—COLOUR SCREENS.—MONOCHROMATIC LIGHT.—COLOUR PHOTOGRAPHY (AUTOCHROME).

Quite a chapter could be written on focussing screens and the mode of preparing them. Fine ground-glass screens can be bought with transparent circles (about  $\frac{5}{8}$  in. diameter) in the centre and four corners, made by cementing thin microscopic cover glasses on with Canada balsam. These will answer all purposes. Some beginners work with a focussing cloth, underneath which they get quite hot and exhausted. If the gas in the room be turned down, there is no necessity for a cloth, and focussing can be carried on with comfort. It is well to sit down to the work and take it easy; standing and bending the back are tiring.

To focus, the focussing glass is held in one hand, leaving the other hand free for focussing first with the coarse and then with the fine adjust-



HYDRA FUSCA.



Multiple colour illumination, showing how the difference between a transparent object and its background may be accentuated without staining.



ments and for moving the mechanical stage and iris diaphragm, all of which may be easily reached. The rough focussing should be done through the eyepiece, with the camera and sliding block removed, as explained previously.

After the camera is replaced, a little time in trying different effects will not be wasted, for there is no possibility of getting a perfect picture by a lucky shot, as sometimes happens when using a hand camera. There is no place for chance in photo-micrography, and a scientific worker whose aim is to depict Nature just as it is would scorn to "doctor" his negatives for the purpose of pictorial effect.

The effects of closing the iris diaphragm, or a slight oblique light if fine markings are desired, or plain ground-glass between the condenser and the lamp if white diffraction lines are too conspicuous, may all be tried. Perhaps a coloured glass may be better. Then when a suitable result is obtained, one has to be very accurate with the fine adjustment, for everything else goes for nothing if correct focus be wanting.

With very transparent objects contrast can often be improved by lowering the condenser instead of closing the iris diaphragm.

A vertical camera is better for oil immersion objectives, though there is no difficulty when using

them in the horizontal position, if only just sufficient oil be added to make the connection between coverslip and objective. A drop of oil will remain for hours without running or spreading, provided it be carefully and not too profusely applied.

#### FINE FOCUSING WITH HIGH POWERS.

In focussing with high powers, the danger of cracking the cover glass is lessened if the mounted slip be raised from the stage at one edge, using a finger-nail for this purpose, and roughly following up the slip until it is flat on the stage again, when the fine adjustment comes into play.

The finest ground-glass screen is much too coarse to show minute details even when viewed through a focussing glass, and with high powers the projected image on the screen as a rule is anything but brilliant. Some other method must, therefore, be adopted for focussing an object when using, say, such a power as  $\frac{1}{1\frac{1}{2}}$  oil immersion lens. Perhaps the best way is to dispense with the ground-glass screen altogether, and focus from the aerial image caught by a hand reading glass or the Bousfield spectacle lens.

A little practice is certainly essential before the object can be seen at all; but after the knack of catching the aerial image is once mastered, focussing becomes easy.



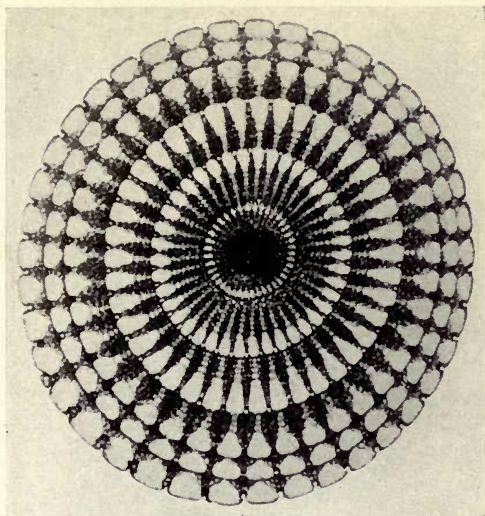


FIG. 21.—Echinus Spine.  $\times 30$ . POSITIVE.

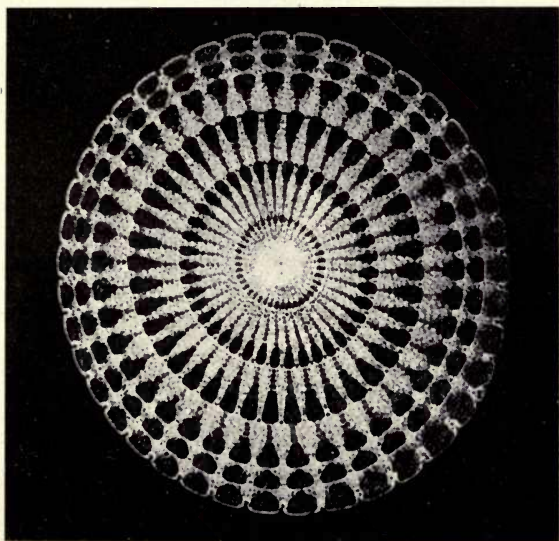


FIG. 22.—Echinus Spine. NEGATIVE.



First throw back the ground-glass screen. leaving the end of camera perfectly open, then place yourself in a position to look right through both camera and microscope, with face about 18in. away from open end of camera. Take an ordinary hand reading glass of, say, 9in. focus, and hold it midway between the eye and the end of camera, moving either the eye or the glass, or both, until the glass is seen full of light with the image of object in centre. After a few trials, not only will the object be seen showing all the finest details, such as would be shown if viewed through the eyepiece on the tube of microscope in the usual way, but the brilliant image enables one to focus the most difficult test object.

The ordinary focussing glass also may be used at the open end of camera, in which case its position would be the same as if it rested on the glass, supposing the glass screen to be there.

There are certain slides sold as test objects, and if the photographer wishes to satisfy himself that his objectives possess power of penetration, definition, flatness of field, and coincidence of visual and actinic foci, he cannot do better than test the value of his lenses by taking a photograph of some well-known object suitable for the power used. Any good book on the microscope will give information on this point. Markings of diatoms, the proboscis of the blowfly, the pygidium of the

flea, podura scales, and sections of wood are well-known objects for such a purpose.

Abbe's test plate is perhaps the best for high powers, though reliable and comparative results can only be obtained after considerable experience with this piece of apparatus.

### DIATOMS AS A HOBBY.

Every possessor of a microscope is sure at some time or other to dabble in diatoms—a group of unicellular plants to be found wherever there is salt or fresh water or damp earth—and for photographic purposes no better objects could be desired. In size they are so tiny as to be almost invisible to the naked eye, yet marked with exquisite patterns of delicate and intricate lacework that attract both novice and specialist alike, and make them the playthings of a microscopist.

Evidently, therefore, Nature does not lavish its gifts of beauty through processes of evolution, for nothing prettier can be found in highly organised structures than in these simple cells of the vegetable kingdom.

When viewed in a living state, a drop of water may show diatoms moving about in numbers and kept free from collision by some mysterious agency not yet known. It is not the living plant, however, so much as its siliceous skeleton in a prepared state that makes it dear to the micro-



scopist, for undoubtedly it was the attempt to make visible all the minute markings of the diatom that brought about such a great improvement in microscopic objectives.

In fact, only objectives of large aperture and first-class construction in the hands of a skilful operator will reveal the dots, beads, and lines of certain test diatoms which run up to 100,000 per inch. Plate IX. shows a pretty effect obtained by grouping diatoms along with the "crown and anchor." For one in search of a hobby, the collection and examination of diatoms will speedily yield a delightful pastime.

To measure the amplification of the object photographed with any extension of camera, a micrometer is placed on the stage, and the divisions on it are also photographed, keeping the camera extension unaltered. Or they may be marked with pencil on the ground-glass screen and distances taken with compasses. The enlargement is measured, and divided by the known distance between the spaces on the micrometer. Thus if 1-100in. on the micrometer measures 1in. on the photograph, the enlargement is 100 times. Or the same result may be got by means of the camera lucida, if the paper be placed as much below the camera lucida prism as the ground-glass screen was from the eyepiece. For purposes of measurement

a 10 in. tube is the standard, and a negative taken 10 in. away from the eyepiece will give an enlargement equal to that seen by the eye when looking through the eyepiece. If the camera be now halved in length the magnification is halved, and if the camera be doubled the increase is in proportion.

A table showing the enlargement due to the various eyepieces and objectives is given by most makers in their catalogues, and may be referred to for ready reference. The same magnification may be obtained by using a low power with the C eyepiece, or a higher power with the A eyepiece, and by altering the camera extension in each case. The photographer must judge which method is best for his purpose, remembering always that a low power objective will give more depth of focus than a high power, and the A eyepiece gives a brighter image than the C eyepiece, consequently shortening the time of exposure.

The list is taken from the catalogues of various makers, and is not based on any scientific system of uniformity. No reliable nomenclature of eyepieces and objectives has yet been adopted for the compilation of consistent tables.

See definition of "Power" in glossary for fuller information.

The unit for microscopical measurement is the micron (written  $\mu$ ), the thousandth part of a milli-

metre, or 1-25400in., but the enlargement itself is usually expressed in diameters, that is, by the number of times the picture is longer than the original object, linear measure only being taken and not superficial area. For example, if an object  $\frac{1}{10}$ in. long were enlarged to 1in., or ten times, it would be said to be magnified ten diameters, usually written  $\times 10$ .

TABLE OF APERTURES AND MAGNIFYING POWERS OF OBJECTIVES WITH EYEPIECES.

| Nominal Focus. |               | Numerical Aperture (N.A.) | Equivalent Angle in Air. | Enlargement with Various Eyepieces, 10in. Tube. |     |     |
|----------------|---------------|---------------------------|--------------------------|---|-----|-----|
| Millimetres.   | Inches.       |                           |                          | A.  | B.  | C.  |
| 51             | 2             | 0.12                      | 15°                      | 30  | 45  | 60  |
| 25             | 1             | 0.24                      | 27°                      | 62  | 93  | 124 |
| 12             | $\frac{1}{2}$ | 0.34                      | 40°                      | 100   | 150 | 200 |
| 6              | $\frac{1}{4}$ | 0.76                      | 98°                      | 250   | 375 | 500 |
| 4              | $\frac{1}{4}$ | 0.83                      | 112°                     | 350   | 525 | 700 |
| 3              | $\frac{1}{4}$ | 0.97                      | 152°                     | 412   | 618 | 824 |

OIL-IMMERSION OBJECTIVE.

|   |                |      |   |     |      |      |
|---|----------------|------|---|-----|------|------|
| 2 | $\frac{1}{15}$ | 1.30 | — | 700 | 1050 | 1400 |
|---|----------------|------|---|-----|------|------|

POLARISCOPE.

The polariscope is indispensable for the study of rocks and crystals. This is an instrument for polarising and analysing the light, and generally consists of Iceland spar prisms mounted for easy

attachment to the microscope, the polariser fitting underneath the object slide, and the analyser above the objective. By its use a pencil of light is split up in such a way that the emergent beam is different from the one which enters, or it may be extinguished altogether in certain positions of the prism. This interference of light waves causes certain substances to appear brilliantly coloured, whereby the structure is differentiated in a marked degree.

It would be difficult, for instance, to get light and shade or variety of form in many substances that are much too transparent for ordinary photography; but with polarised light a contrasty negative can be obtained showing the several tissues or structure in a satisfactory manner.

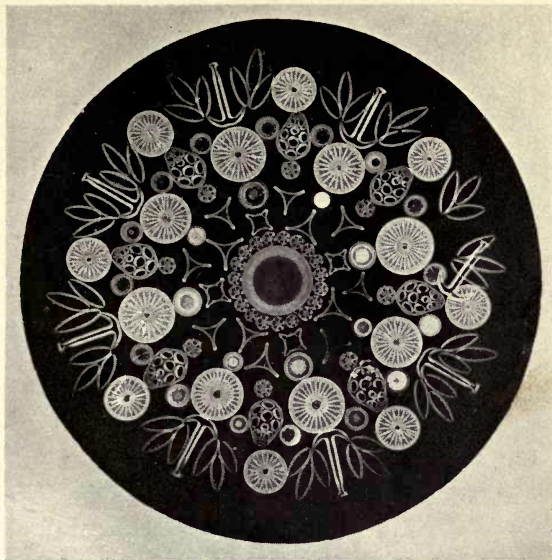
Slips of selenite, as usually supplied, only give blue and yellow or green and red; but either a thin sheet of mica or selenite of varying thickness will often intensify the colour effects in a desired manner. It will be found that sober tints yield better negatives than the gaudy ones, therefore the mica or selenite can be selected accordingly.

A body tube dead black inside is essential, and the most suitable powers are 2in. and 1in. objectives. Under all circumstances a great obstruction of light takes place, hence the eyepiece is dispensed with to compensate for the loss through the prism.

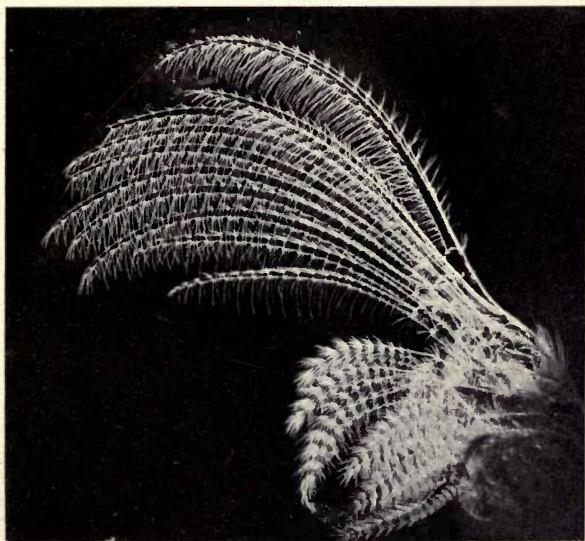


ELEMENTARY PHOTO-MICROGRAPHY.  
PLATE IX.

DARK-GROUND ILLUMINATION.



Diatoms.



Barnacle Cirri  $\times 7$ .



Orthochromatic plates, preferably backed, are used for this class of work, and in rotating the prism a position can be selected that passes much more light than any other position. Perhaps the position, however, may not give the most desirable colours. Should this be so, try a change of mica or selenite, and if not now satisfactory, adopt such a medium position of the prism as shall be found to combine the greatest possible amount of light with satisfactory contrasts of colour. With the polariscope the time of exposure is about doubled.

The following substances will be found particularly suitable for a display of colour and pattern.

|                     |                     |
|---------------------|---------------------|
| Sugar.              | Coumarin.           |
| Chlorate of potash. | Aspartic acid.      |
| Brucine.            | Sulphate of copper. |
| Salicine.           | Distillation from   |
| Sections of rock.   | vapour of coke.     |

In landscape photography, colour screens are used to obtain correct colour values, but in photo-micrography they are used for quite a different purpose, viz., to secure contrast. For instance, bacteria and many anatomical and vegetable sections are so transparent that they have to be single or double-stained before it is possible to differentiate their form and structure. In their original colourless state they would never give a well-defined photograph, hence artificial contrasts have to be

produced by staining. The general rule for determining the particular colour screen to be used for insertion between the light and the object during exposure is that it should be the complementary colour of the one on the object. Thus if the stain be red, a green screen must be used, because a red object viewed through a green glass will appear black, and blackness or absence of light will give more or less transparent places on the negative, an essential element in the production of vigorous pictures. Experiment alone will teach the student just the right tint to employ. He should therefore have a selection not only of colours, but of light and dark shades. When colour screens are used, the acetylene light reduces exposure, and gives better results than the oil lamp. Orthochromatic plates must be used in every case.

Exposure with green screen is lengthened about three times, and with red five times.

The use of a signal-green glass between the lamp and microscope will vastly improve the definition of any achromatic objective. Note that the colour screen should be placed in position before the focussing of image on the camera screen is completed, and not after.

Monochromatic light is often essential for the very best results. This is light of one colour and one uniform wave length. Images formed by waves



of different lengths may destroy each other. The longest wave is red, and the shortest violet. Every colour has a different wave length, and the separating power of objectives increases as the length of light wave diminishes: that is, if the wave length be reduced, it is equivalent to increase of aperture.

A pamphlet on photo-micrography by the Wratten Division of Kodak, Ltd., Kingsway, London, deals with the selection of light filters for coloured objects in an elementary but thorough manner, and shows clearly how to increase or diminish contrast between the structure of the object and its background; or, if the object be colour-stained, how best to control the colour of the light used for illumination in order to secure good results.

From this pamphlet, which can be obtained on application from the firm named, the following extracts are taken:

“When white light is examined in a spectro-scope, the analysis shows a band of colours which appears to consist of three main portions: red, green, and blue-violet. If objects of various colours be examined, it will be found that a light blue object has an absorption band in the red, a purple object in the yellow, a magenta in the green, an orange in the blue-green, and a yellow

in the blue-violet. Thus a sensation of light blue is produced by a mixture of green light and blue-violet light falling upon the eye, the red light being more or less absent, having been absorbed from the white light by the object, which appears to be coloured light blue.

“ If a colour is to be rendered as black as possible, then it must be viewed or photographed by light which is completely absorbed by that colour.”

In other words the light filter should be of a complementary colour to that of the object.

Another rule for procedure deals with the case where contrast is required, not against the background but within the object itself.

“ A good case of this is the photography of an unstained section of whalebone. This is of a yellow colour, and shows ample detail to the eye, but it completely absorbs blue-violet light; and if it is photographed on an ordinary plate sensitive only to blue violet light, then it shows far too much contrast, appearing as a black detail-less mass against the background, and presenting an exaggerated example of the loss of detail which has already been noted in the eosine section photographed by light which it completely absorbs. The proper procedure in this case is to photograph the object by the light which it transmits.

The whalebone section, for instance, photographed by red light gives perfectly satisfactory results showing ample detail in structure."

As a general guide, when contrast is required use for stained preparations filters as under :

For blue use a red filter.

|          |          |   |
|----------|----------|---|
| „ green  | „ red    | „ |
| „ red    | „ green  | „ |
| „ yellow | „ blue   | „ |
| „ brown  | „ blue   | „ |
| „ purple | „ green  | „ |
| „ violet | „ yellow | „ |

#### LIST OF WRATTEN " M " FILTERS.

| <i>Name of Filter.</i> |    |    |    | <i>Visual Colour.</i> |
|------------------------|----|----|----|-----------------------|
| A                      | .. | .. | .. | Scarlet               |
| B                      | .. | .. | .. | Green                 |
| C                      | .. | .. | .. | Blue-violet           |
| D                      | .. | .. | .. | Purple                |
| E                      | .. | .. | .. | Orange                |
| F                      | .. | .. | .. | Pure red              |
| G                      | .. | .. | .. | Strong yellow         |
| H                      | .. | .. | .. | Blue                  |
| K <sub>3</sub>         | .. | .. | .. | Bright yellow         |

By using these screens together, the spectrum can be divided up into monochromatic portions, thus :

| <i>Name of Filter.</i> |    |    |    | <i>Visual Colour.</i> |
|------------------------|----|----|----|-----------------------|
| A and D                | .. | .. | .. | Deep red              |
| A and B                | .. | .. | .. | Brown                 |

| <i>Name of Filter.</i> |       | <i>Visual Colour.</i> |
|------------------------|-------|-----------------------|
| B and E                | .. .. | Yellow-green          |
| G and H                | .. .. | Pure green            |
| B and C                | .. .. | Blue-green            |
| D and H                | .. .. | Violet                |

As a general guide, the following list of the chief microscopic stains with the filters to be used may be of advantage :

| <i>Stain.</i>  |       | <i>Screen to be used.</i> |
|----------------|-------|---------------------------|
| Aniline blue . | .. .. | B and E                   |
| Bismark brown  | .. .. | C                         |
| Congo red ..   | .. .. | B and C                   |
| Eosine ..      | .. .. | G and H                   |
| Erythrosine .. | .. .. | G and H                   |
| Fuchsine ..    | .. .. | B and G                   |
| Gentian violet | .. .. | B and E                   |
| Hæmatoxylin    | .. .. | B and C                   |
| Iodine green   | .. .. | F                         |
| Methylene blue | .. .. | D and G                   |
| Methyl violet  | .. .. | B and E                   |
| Methyl green   | .. .. | F                         |
| Picro carmine  | .. .. | G and H                   |
| Rose Bengal .  | .. .. | G and H                   |

For insects and yellow sections generally, photograph as follows :

FOR CONTRAST, with a C screen.

FOR DETAIL in the section, with an F screen.



## COLOUR PHOTOGRAPHY (AUTOCHROME PROCESS).

The colour effects shown by the polariscope may be easily reproduced on Autochrome plates. For this purpose the special filter screen supplied by the Lumière Co. should be attached to the inside of camera, and the focussing screen be reversed—that is, placed with the rough side outwards.

The Autochrome plate is put into the dark slide with the emulsion surface inwards, so that the glass side faces the microscope.

With incandescent gas and 3in. objective, an exposure of from one to one and a half hours will be necessary. Subsequent operations are as follow :

Develop with metoquinone for two and a half minutes, and then wash. Reverse the image with a solution made up just before use as under :

|                          |               |        |
|--------------------------|---------------|--------|
| Potassium permanganate . | 2             | grains |
| Sulphuric acid .. ..     | $\frac{1}{8}$ | dram   |
| Water .. ..              | 2             | ounces |

After covering the plate with this solution, bring the dish out into full light, and allow it to remain three or four minutes, rocking the dish frequently meanwhile.

Wash for half a minute.

Now redevelop with the original developer till the plate goes black, which usually takes about three minutes. Wash again for three minutes, and put out to dry.

A varnish made of

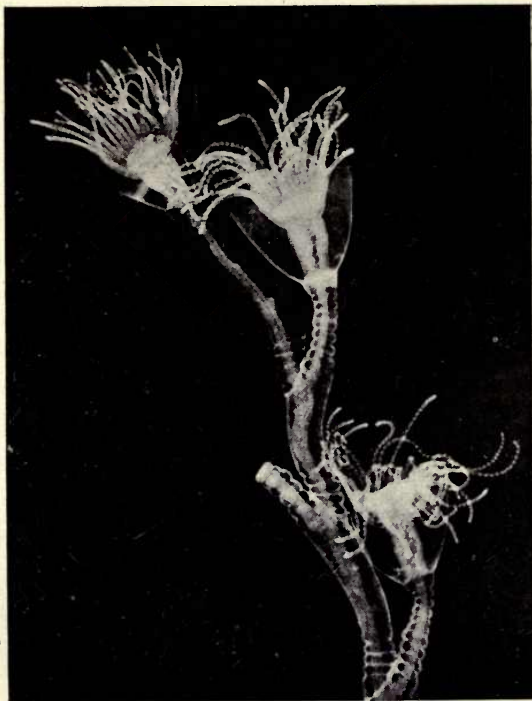
Gum dammar    ..    ..    1 ounce

Benzole    ..    ..    5 ounces

will protect the surface, and render the plate more transparent. A further protection is afforded by a cover glass bound up like a lantern slide.

ELEMENTARY PHOTO-MICROGRAPHY.  
PLATE X.

DARK-GROUND ILLUMINATION.



Bell Coralline     $\times 20$ .





## CHAPTER VIII.

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EXPOSURE. — DISCOLOURED BALSAM. — COMPARATIVE VISIBILITY IN DIFFERENT MEDIA.—AN EXPOSURE RECORD.—EXAMPLES OF EXPOSURE.—FLASHLIGHT EXPOSURE.—HOW TO PHOTOGRAPH MULTIPLE IMAGES THROUGH THE COMPOUND EYE OF AN INSECT.—RECORD WORK AND CIRCULATING ALBUM FOR MICROSCOPICAL SOCIETIES. — PHOTO-MICROGRAPHIC SOCIETY.—QUEKETT MICROSCOPICAL CLUB.—ROYAL MICROSCOPICAL SOCIETY.

So much depends upon the light, the power of lens and eyepiece used, the colour and opacity of the object, camera extensions, etc., that only an approximate estimate may be made from the results of another worker; but the exposures tabulated hereafter were obtained with a paraffin lamp having a wick 1 in. wide. A word of warning may be given concerning specimens mounted in balsam. If one of these show patches of deeper colour in some parts than others, or if the gold size, marine glue, or other material of which the cell is constructed has dissolved and stained its contents, it should be rejected forthwith, for no amount of tinkering will give a good negative.

Slides deep yellow on one side and perfectly transparent on the other, whilst not unfit for visual examination, are quite unsuitable for photography. This shows that some attention ought to be paid to the quality of the mounting.

Again, the kind of medium in which the object is mounted will largely determine the character of the photograph, more particularly with high powers. Many varieties of preservative, resinous and chemical media are employed for slide mounting, and advantage can be taken of such as have a high refractive index to bring out distinctly all possible details.

Van Heurck says that any object inserted in a liquid is visible according to the amount of difference between the refractive indices of the medium and the object; and by way of example he compares a diatom mounted in water with one mounted in styrax, and also in monobromide of naphthalin.

The silica of diatoms has a refractive index of 1.43, and the index of water is 1.33, so that the difference, viz., 10, expresses the visibility in water. With styrax this difference is 17, and with monobromide 22. With realgar a much greater difference can be obtained; but unfortunately good mounts in this medium are difficult to obtain.

A record of all exposures should be kept, entering the failures as well as the successes ; it should note the plate used, the class of object photographed, with its characteristic quality, the exposure, the distance of the plate from the object, and the result with each power and with each class of illumination. Supposing this to be done, and one wishes to know what exposure to give to a cheese mite, using the 1in. objective and the A eyepiece, reference to the register shows, say, the following :

## EXPOSURE RECORD BOOK.

1in. Objective.      Transmitted Light.

| Power used. | Eyepiece. | Condenser. | Camera Length. | Tube Length. | Mode of Illumination. | Object.     | Plate. | Colour Screen. | Exposure. | Result.    |
|-------------|-----------|------------|----------------|--------------|-----------------------|-------------|--------|----------------|-----------|------------|
| 1           | A         | None       | 10             | 10           | T                     | Cheese mite | Slow   | Green          | 10m.      | Too little |
|             |           |            |                |              |                       |             |        |                |           |            |
|             |           |            |                |              |                       |             |        |                |           |            |
|             |           |            |                |              |                       |             |        |                |           |            |
|             |           |            |                |              |                       |             |        |                |           |            |
|             |           |            |                |              |                       |             |        |                |           |            |
|             |           |            |                |              |                       |             |        |                |           |            |

Under the head of Illumination, the following abbreviations may be used: T, for transmitted light; R, reflected light; D, dark ground; O, oblique illumination; P, polariscope.

This will give an idea of the correct exposure for any similar class of specimen. It is folly to rely on the memory alone, like so many landscape photographers do. Far better take every precaution suggested by previous experiments to ensure correct exposure. One must not move about during the time of exposure, for vibration will spoil the sharpness of any negative, especially with high powers. It is not necessary, however, to remain inactive, for the gas may be turned full on, and the time occupied by reading or writing. When very long exposures are made, the worker may even leave the room and return at the end of an appointed time, so being free to do other things meanwhile.

The conditions governing correct exposure are so varied that no rule can be stated, and the following examples are merely given to point out the probable variations likely to occur in photographing assorted specimens. The distance of the object from the plate was about 18in., the source of illumination a paraffin lamp with a 1in. wick.



## A FEW EXAMPLES OF EXPOSURE.

## 3IN. OBJECTIVE.

|                    |   |
|--------------------|---|
| Transmitted Light. | <i>Section of Human Tongue.</i> Red. "A" eyepiece. No condenser. Chromatic plate. One minute.<br><i>Leg of Fly.</i> Brown. Ground-glass interposed between lamp and object to secure sharpness of hairs and reduce the white diffraction effects. "A" eyepiece. Slow plate. Four minutes. |
| Dark Ground.       | <i>Polycystina.</i> Slow plate. Webster condenser. "A" eyepiece. Four minutes.  |
| Reflected Light.   | <i>White Coralline.</i> No eyepiece. Slow plate. Side reflector. Five minutes.  |
| Polariscope.       | <i>Tongue of Whelk.</i> No eyepiece. Chromatic plate. Five minutes.   |

## 2IN. OBJECTIVE.

|                    |  |
|--------------------|--|
| Transmitted Light. | <i>Beetle's Eye.</i> Section. Slow plate. Three minutes. "A" eyepiece. No condenser. |
| Reflected Light.   | <i>Diatoms</i> mounted as opaque objects. Slow plate. Four minutes. "A" eyepiece.    |
| Dark Ground.       | <i>Polycystina.</i> Webster condenser. Slow plate. Four minutes. "A" eyepiece.       |
| Polariscope.       | <i>Brucine.</i> Eyepiece removed. Chromatic plate. Eight minutes.                    |

## 1IN. OBJECTIVE.

|                    |  |
|--------------------|--|
| Transmitted Light. | <i>Diatoms.</i> "A" eyepiece. Slow plate. Four minutes.<br><i>Wing of Fly.</i> Slow plate. One minute. |
| Reflected Light.   | <i>Foraminifera.</i> "A" eyepiece. Rapid plate. Ten minutes.   |
| Dark Ground.       | <i>Diatoms.</i> Slow plate. "A" eyepiece. Sixteen minutes.<br>Ditto. Ditto. No eyepiece. Ten minutes.  |
| Polariscope.       | <i>Aspartic Acid.</i> No eyepiece. Chromatic plate. Eighteen minutes.                                  |

$\frac{1}{4}$ IN. OBJECTIVE.

|                    |   |
|--------------------|---|
| Transmitted Light. | <i>Section of Deal.</i> "A" eyepiece. Rapid plate. Ten minutes. |
|--------------------|---|

 $\frac{1}{8}$ IN. OBJECTIVE.

|                    |  |
|--------------------|--|
| Transmitted Light. | <i>Human Blood.</i> "A" eyepiece. Chromatic plate. Green colour screen. Thirty-five minutes. |
|--------------------|--|

 $\frac{1}{12}$ IN. OIL IMMERSION.

|                    |   |
|--------------------|---|
| Transmitted Light. | <i>Bacteria.</i> Stained red. "A" eyepiece. No colour screen. Chromatic backed plate. Twelve minutes.<br>Ditto, with green colour screen. Thirty minutes. |
|--------------------|---|

## \* INSTANTANEOUS EXPOSURE IN PHOTO-MICROGRAPHY.

Although flashlight has been in common use for purposes of ordinary photography, it has not been tried within the writer's knowledge for photographing through the microscope; but, in the absence of a powerful illuminant, such as the electric light, a ready and simple substitute can be provided whenever the exposure of a fractional part of a second is needed.

In preparing illustrations of pond life, for example, preference is given to dead specimens mounted without pressure, for the simple reason that a time exposure is impossible with anything

\* Paper read before the Royal Microscopical Society, October 18th, 1911.

not absolutely at rest; hence many amateurs will welcome a method that places in their hands a convenient process of photographing objects in motion. Experiments were first made with fresh-water polyzoa, *Lophopus crystallinus*, expanding its tentacles—a movement not too rapid for good definition at 1-30th second. The microscope was horizontal with object in vertical cell on the stage, which was focussed by properly adjusted transmitted light from oil lamp in the ordinary way, and provision was made for replacing the lamp by a tin dish containing “Agfa” flashlight powder on a retort stand arranged to bring the powder in the position previously occupied by centre of lamp flame, the top of powder being at the level of bottom of flame. Ignition can then be made at a suitable moment by means of a long taper or red-hot wire.

To ascertain the most advantageous time for exposure, a dim light should be thrown on the subject obliquely either from behind or in front, sufficient to reveal the outlines when looked at through a hand magnifying glass. The other lights in the room should then be lowered, and the shutter of dark slide withdrawn.

Standing in readiness for any desired display of outline, it is easy to fire the powder very quickly.

Some well defined negatives were secured when using 2in. objective with  $\times 5$  eyepiece. It is

advisable to take precaution against any scattered red-hot particles reaching the microscope by interposing a sheet of plain glass between the powder and the instrument. The quantity of powder is immaterial, as its complete combustion is always 1-30th second, whilst the maximum light develops in less than 1-100th second. Only a very little smoke is evolved, which is quickly dispersed. In this way I have photographed the larva of caddis fly protruding from its case, water shrimps, etc., but have not yet succeeded in obtaining good definition with darting or rapidly moving objects. There was no trouble from uneven lighting.

#### HOW TO PHOTOGRAPH MULTIPLE IMAGES THROUGH THE COMPOUND EYE OF AN INSECT.

Gosse, in his book "Evenings at the Microscope," states that there are 24,000 lenses in the two eyes of a dragon fly. "Every one of these 24,000 bodies represents a perfect eye ; every one is furnished with all the apparatus and combinations requisite for perfect vision, and there is no doubt the dragon fly looks through them all."

This fact is often demonstrated by placing one of these compound eyes, mounted flat on a glass slip, on the stage of the microscope, when any well-defined object may be seen repeated in each of the facets. As a matter of curiosity this is most



ELEMENTARY PHOTO-MICROGRAPHY.  
PLATE XI.

TAKEN BY FLASHLIGHT.



Living Campanularia in sea water.



interesting, and it affords excellent practice in the art of focussing. The picture of the object to be repeated should be first made on a lantern slide in the usual way, and masked to show only the part to be photographed. This should be small enough to show as a transparency within an opening of  $\frac{1}{2}$  in. square, the rest of the slide being blocked out. With the microscope in its horizontal position, place this transparency vertically about midway betwixt the lamp and substage condenser, and at the right height to correspond with axis of microscope and the prepared eye (which can be purchased for 1/6) on the stage. The 1 in.,  $\frac{1}{2}$  in., or  $\frac{1}{4}$  in. objective can be used either with or without eyepiece. First try with  $\frac{1}{2}$  in. objective and "A" eyepiece, and focus on the mounted eye. It is at this point where difficulty occurs, but it must be remembered that what has to be found is the aerial image of the object as it is focussed by the lenses of the compound eye, which will be at a point nearer to the observer than the plane of the eye on the glass slip. If, therefore, the objective be very slowly racked out of focus, a point will be reached when an image will be seen in every facet of the eye.

The size of the image as well as its sharpness may be varied by moving the transparency to or from the condenser, or by altering the focus of

substage condenser or the objective. When satisfactory definition is obtained, couple up the camera and photograph.

#### RECORD WORK AND CIRCULATING ALBUM FOR MICROSCOPICAL SOCIETIES.

It sometimes happens that an object is under observation of which a record is desirable, and of which it is not possible to obtain a slide prepared and mounted for photography. When such an occasion arises, as it often does in the study of pond life, more particularly the very transparent infusoria, a sketch can be drawn to scale with sufficient exactness for purposes of identification by using a micrometer ruled in squares in the eyepiece. This consists of a thin glass disc mounted in a brass ring, as sketch, fig. 23, on which a square is drawn, having each side divided into ten parts, thus giving a space ruled into 100 squares. Every portion of an object under view, therefore, is seen to lie in one or other of these divisions, as in fig. 23.

A similarly ruled square, but enlarged, say, ten times that in the eyepiece, is made on paper, when it is an easy matter to transfer the outline of any object from one square to the other.

Such sketches in microscopical societies may be advantageously made on white cards of uniform



size,  $5 \times 4$ , when they serve a two-fold purpose. First, that of encouraging members to make careful and accurate observations, and, again, of recording the work done by the society. Members, too, will find the subsequent identification and classification of species greatly accentuate their interest.

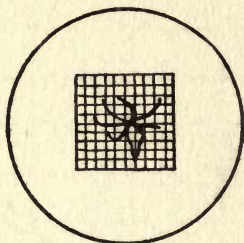


FIG. 23.

The front of card is shown in fig. 24, with sketch, or preferably a photograph, pasted on, and the back of card in fig. 25.

Power of objective and eyepiece, mode of illumination, brand of plate, and exposure may be added where necessary.

The cards should then be inserted in an album from which they can be readily withdrawn, and the album put in circulation for any definite period. After return from its round, the album is refilled with fresh cards, whilst the old ones are put in classified boxes and scheduled. If two or more

members contribute pictures of the same object, naturally the best is selected for reference.

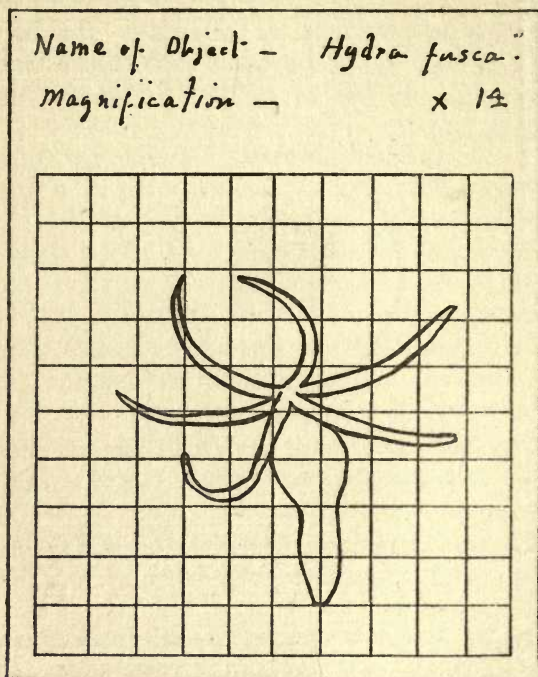


FIG. 24.—Front of card.

Such a definite plan is of great educational value, especially if a manuscript book for criticism or additional information accompany the album.

Small flat tubes, which can be placed on the stage of microscope, are very handy for the rough examination of pond life. They are  $\frac{3}{8}$  in. long,

|                  |  |
|------------------|--|
| Date             |  |
| Where found      |  |
| Kingdom          |  |
| Sub-kingdom      |  |
| Class            |  |
| Order.           |  |
| Family           |  |
| Genus            |  |
| Species          |  |
| <i>Remarks :</i> |  |

FIG. 25.—Back of card.

$\frac{3}{8}$  in. wide, and  $\frac{1}{8}$  in. thick, with rounded neck at one end to take a cork. Photographs of the coarser kinds of plant and animal life may be taken without any trouble of mounting.

Workers would find many advantages from joining the Photo-micrographic Society, which meets in King's College Bacteriological Laboratory, Charing Cross.

Exhibitions of work and demonstrations are held during the session. Subscription 7s. 6d., including copy of the Society's journal, issued twice during the session. Visitors are welcomed at the ordinary meetings. Full particulars may be got from Mr. Bradbury, hon. sec., 1, Hogarth Hill, Finchley Road, Hendon, N.W.

There are also several microscopical clubs in existence, any of which might help a beginner to sustain interest in his work; but the principal societies are the Royal Microscopical Society and the Quekett Microscopical Club. For purposes of mutual help, the Quekett Club offers great advantages. There is a fine library of books, also a cabinet of slides, which may be borrowed, and members living in the provinces can make arrangements to have these forwarded.

Gossip nights give an opportunity for sociability and obtaining information on any subject connected with microscopy. Pond life is a great feature of the club, and excursions are frequently made to collecting grounds in the district. Papers read before the club appear in an illustrated journal issued twice a year, but reports of monthly meet-



ings, printed in *The English Mechanic*, are posted to country members.

No entrance fee. Annual subscription, 10s.  
Address.—20, Hanover Square, London, W.

The Royal Microscopical Society is the principal society in the world, and its journal, issued bi-monthly, contains up-to-date information in all branches of microscopical work both here and abroad.

Entrance fee, two guineas.

Annual subscription, two guineas.

Address : 20, Hanover Square, London, W.

## CHAPTER IX.

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REQUISITES FOR DEVELOPMENT.—APPARATUS.—  
CHEMICALS.—PRICES.—SUITABLE PLATES.—  
DEVELOPERS FOR NEGATIVES.—FOR LANTERN  
SLIDES.—FOR BROMIDE PAPERS.—TIME  
DEVELOPMENT.

Many people have the impression that the work of development must be carried on with a miserable light from a ruby lamp, and consequently inflict upon themselves trials of patience, until a bad headache compels them to stop, or their powers of endurance are exhausted. Never was a greater fallacy. For ordinary plates a lamp may be used giving plenty of yellow light, so that everything can be plainly seen and all operations carried on with comfort. Only when using chromatic plates is a red light necessary. Even with this a lamp having a large red glass front, not too deep, will give great relief, for small lamps are an abomination. In cases where a dark room is not available, the work can be done at night in an ordinary bathroom. Gas is the best illuminant, and lamps are sold that will give red, yellow, or white light at pleasure. Failing gas, the next handiest lamp is a candle-lamp. Candles worked by springs are apt to be very provoking. The light sometimes

either goes out or splutters the grease all over the glass at a critical moment, and oil lamps smell and are dirty. The best all-round lamp is a canary-coloured hock bottle over a good wax carriage candle. Only good wax candles should be used ; the cheap " Stearine " kind bend over from the heat and crack the glass cover.

The following apparatus and chemicals will be sufficient for a quarter-plate outfit :

Two developing dishes, with a lifter at one end to raise the plate, so that it can be grasped at the edges and lifted out for examination. This simple rocking lever fixed in the end of the tray enables one to keep one's fingers almost free from contact with the chemicals—a great boon, preventing both rough skin and stained fingers.

Two glass graduated measures.

A vertical fixing trough with six frames for plates. The advantage of the vertical position is indisputable, and as the hypo can be kept permanently in this trough, it is always ready. Any plate can be lifted out for inspection without wetting the hands.

A porcelain washing trough with grooves for twelve quarter-plates placed vertically side by side.

One ditto for lantern plates.

A print washer.

A graduated water jug.

A drying rack.

Two or three large dishes for water, hypo, and acid baths, used for bromide and platinotype prints; also one for toning if p.o.p. be used.

A hand magnifying glass.

Pins.

Mounting paste.

Weights and scales.

Funnels.

Print clips for suspending prints from a line while drying.

A dropping bottle for potassium bromide.

Six printing frames.

A printing frame for making lantern slides.

Masks and mounts.

Cover slips for lantern slides.

A retouching desk.

Towels and a sponge.

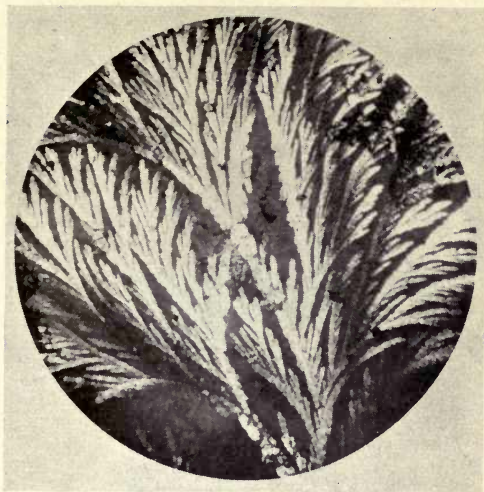
The reader is advised to make his own developers. Chemicals of the kind and quantity given will be found ample for a start:

|                    |       |         |    |          |
|--------------------|-------|---------|----|----------|
| Alum               | .. .. | 4 ozs.  | at | 2d. lb.  |
| Acetic acid        | .. .. | 8 ozs.  | „  | 2d. oz.  |
| Citric acid        | .. .. | 2 ozs.  | „  | 2d. oz.  |
| Hydrokinone        | ..    | 1 oz.   | „  | 10d. oz. |
| Hydrochloric acid  |       | 5 ozs.  | „  | 1d. oz.  |
| Methylated spirit  |       | 10 ozs. | „  | 6d. lb.  |
| Mercury bichloride |       | 1 oz.   | „  | 4d. oz.  |

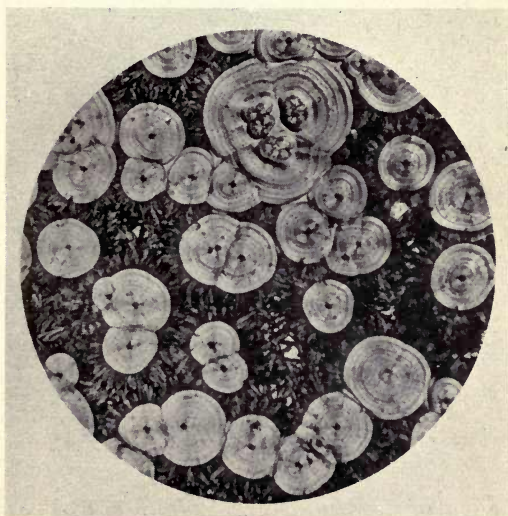


ELEMENTARY PHOTO-MICROGRAPHY.  
PLATE XII.

POLARISCOPE.



Sulphate of Copper.  $\times 8$ .



WITH POLARISED LIGHT.

Brucine. No eyepiece. 2in. objective. Chromatic plate.  
Ten minutes.



|                      |        |    |          |
|----------------------|--------|----|----------|
| Nitric acid .. ..    | 2 ozs. | at | 1d. oz.  |
| Oxalic acid .. ..    | 2 ozs. | „  | 6d. lb.  |
| Pyrogallic acid      | 1 oz.  | „  | 11d. oz. |
| Potassium oxalate    |        |    |          |
| (neutral) .. ..      | 2 ozs. | „  | 1d. oz.  |
| Potassium bromide    | 1 oz.  | „  | 2d. oz.  |
| „ ferricyanide       | 1 oz.  | „  | 3d. oz.  |
| „ carbonate ..       | 4 ozs. | „  | 6d. lb.  |
| „ metabisulphite     | 2 ozs. | „  | 3d. oz.  |
| Sodium carbonate,    |        |    |          |
| washing soda will do | 1 lb.  | „  | 4d. lb.  |
| Sodium hyposulphite  | 1 lb.  | „  | 2d. lb.  |
| „ sulphite ..        | 1 lb.  | „  | 6d. lb.  |
| „ hydrate ..         | 1 oz.  | „  | 2d. oz.  |

Some brands of plates, particularly in warm weather, have a tendency to frill and pucker at the edges, which, if not stopped in time, will result in the film separating from the plate. Soft gelatine or prolonged development or washing may cause it.

The best way, of course, is to reject any kind of plate that constantly gives this trouble, but it may be prevented by first rubbing the edges of the plate with a wax candle before the developer is poured on. This will keep the liquid from penetrating between the film and the glass. The following kinds of plates will be found satisfactory:

For low powers (slow), Imperial "Ordinary." and Ilford "Ordinary."

For high powers (rapid), Imperial "Sovereign."

For colour contrasts, Ilford "Versatile Ortho.," Imperial "N.F." (non-filter), and "Wratten" plates.

For lantern slides, Ilford "Special" and Cadett Black Tone.

Backed plates give better negatives, but are messy, so, until the worker gains experience, it is better for him to commence with the unbacked plates. For negatives of any kind nothing beats the pyro-soda developer.

It is believed that backed plates require longer exposure than plates not backed, though if any difference in speed it is quite imperceptible, and some makers of well-known brands state that "backing" makes no difference whatever. Backed plates, however, ought not to be kept in stock quite so long as plates not backed.

#### PYRO-SODA DEVELOPER.

##### No. 1, or A.

|                          |    |    |            |
|--------------------------|----|----|------------|
| Pyrogallic acid          | .. | .. | 60 grains. |
| Potassium metabisulphite | .. | 15 | „          |
| Water                    | .. | .. | 10 ounces. |

##### No. 2, or B.

|                 |    |    |            |
|-----------------|----|----|------------|
| Washing soda    | .. | .. | 1 ounce.   |
| Sodium sulphite | .. | .. | 1 „        |
| Water           | .. | .. | 10 ounces. |



Four drams of A and four drams of B, with five drops of 10% solution of potassium bromide, are taken for a quarter-plate.

For lantern slides the writer finds that hydrokinone is the most generally convenient. It may be made up as follows :

#### HYDROKINONE DEVELOPER.

| A.                |    |    |            |
|-------------------|----|----|------------|
| Hydrokinone       | .. | .. | 80 grains. |
| Potassium bromide | .. | .. | 15 „       |
| Sodium sulphite   | .. | .. | 1 ounce.   |
| Water             | .. | .. | 10 ounces. |

| B.             |    |    |            |
|----------------|----|----|------------|
| Sodium hydrate | .. | .. | 50 grains. |
| Water          | .. | .. | 10 ounces. |

Equal parts of A and B are taken to make one ounce of developer.

Hydrokinone is a developer that answers equally well with ordinary plates, lantern plates, and bromide prints ; and after the beginner has obtained some proficiency, he may find it a convenience to have only one developer instead of several.

Rodinal, kachin, metol, and numerous other developers recently placed in the market can be tried after mastering development with the simple standard developers previously mentioned.

With all modern high or slow speed plates there will be found instructions for using the particular developer recommended by the makers.

#### TIME DEVELOPMENT.

The Watkins system of developing by time is now often used. This is based on the time between pouring on the developer and the first appearance of any image. A multiplying factor is given for various developers to secure a standard amount of contrast.

## CHAPTER X.

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CLEANLINESS AND ITS IMPORTANCE.—DEVELOPMENT. — FIXING. — HYPO ELIMINATORS. — STORING NEGATIVES.—CLEARING SOLUTION.—PINHOLES.—INTENSIFICATION.—REDUCTION.

Cleanliness in photography is a most important item. All dishes, glasses, etc., must be well washed before being put away, so that when next used all articles will be clean. They should not be left dirty, with the idea that one will have a more favourable opportunity to tidy later on. An orderly systematic arrangement will simplify matters very much, and render operations more pleasant. Each dish should be kept for its own separate purpose. Do not have for a motto, "A place for everything, and nothing in its place."

Supposing the beginner to be only making a first attempt at development, let him place the fixing trough, lamp, developing dish, and measure containing sufficient developer for his plate in position in readiness on a table, and then assure himself that the room is safely lighted. A jug of water for diluting the developer, if necessary, should be handy, as well as a vessel of water for rinsing the plate before fixing. If the dark room contains a sink and water tap operations are much facilitated.

All these preparations being made, the dark slide is opened and a plate put in the dish, gelatine side up, taking care not to touch the gelatine side with the fingers. Plates must always be lifted by the edges. If the dark slide has been kept clean, there is no advantage in first brushing the slide with a camel-hair flat brush or with velvet, as the danger of leaving dust specks on the plate is as great as getting them from the dark slide. The plate should not be washed before development.

The developer must be swept over it quickly in such a way that no part of the plate is left dry, even for a moment, and the dish gently rocked to keep the solution constantly on the move all over the surface of the plate. If the developer be insufficient in quantity, dry places will be noticed on the plate, over which the developer will not readily flow. This should not be allowed. The developer should be used at a temperature of about 60° F. In very cold weather this is important, or the action, if there is any at all, will be slow.

With the thermometer and developer at freezing point, it is possible for a properly exposed plate to show no signs of any image for quite a long time, whereas on warming the solution development will proceed in a normal manner.

Boiled water that has gone nearly cold may be used, commencing with less than the full quantity



of B solution, and gradually adding more if development be too slow.

A dilute developer is safest for a beginner. In half-a-minute or more traces of the image will begin to appear if the exposure has been correct, and development must be continued until sufficient density be obtained. There should be no hurry. Under-development is a fault of most beginners. If the narrow strips at the edges of the plate which have not been exposed keep white no danger of fogging need be feared. The plate may be lifted out occasionally and held up to the lamp to view the image, looking at the back of the plate also to see if the image appears at that side. If the object shows clearly and is well defined when held against the light, and also shows on the back of the plate, development may be considered sufficient.

A good printing density will be secured if development be continued until it has acted through the full thickness of film and the background appears quite black on the other side of plate, though it is possible to clog fine details by over-development, and spoil the printing quality of the negative.

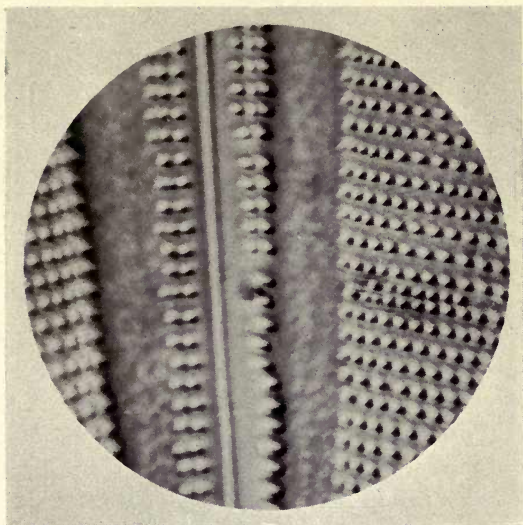
It would assist a beginner to form a correct judgment about density if he borrowed a correctly exposed and developed plate from some friend. This would serve as a standard with which comparison of his own results could be made at leisure.

If, however, the whole image appears thin and ghost-like, there is a fault in the exposure. Should the high lights represented by black places on the negative come up slowly and the other details do not follow, the plate is under-exposed. With patience, perhaps a printable negative may be got, but as a rule it is better to throw it away and make another. If, on the other hand, the image rushes up quickly, the plate is over-exposed and the developer must be diluted, adding also more bromide to prevent fogging.

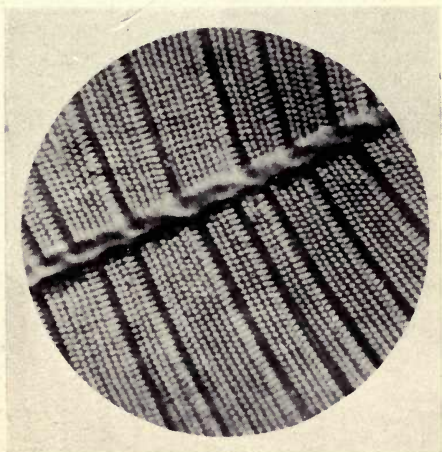
After development is completed, the plate may be washed in water and put in the fixing bath to stay fifteen minutes.

From this it is transferred to the washing trough, and the water changed eight times, allowing it to soak for five minutes between each change. The back of the negative is then dried with a cloth or blotting paper, and it is put into the rack to dry. The rack should be in a warm room free from dust, but not too near a fire lest the gelatine melt and spoil the plate. Slow drying will often spoil the negative by leaving various degrees of density in the film.

Flooding the plate with methylated spirit will assist quick drying. If tap water be used for washing, it should be seen that it is not charged with air, which causes the gelatine to separate



Navicula Lyra.  $\times 1200$ .



Surirella Gemma.  $\times 1700$ .







from the glass, or blisters it in such a way as to disfigure the print.

Running water, where available, is more effective in dissolving out the hypo, from which the negative should be freed, though it has no special virtue, as change of water is the main point. Besides, it is often not obtainable, and leads to waste.

Sometimes a plate may have to be developed late at night, when it would be risky to leave it soaking in water till next day, especially in warm weather. The Hypax tablet or Hypono solution in such a case will be found an excellent substitute for prolonged washing. After the plate has been well rinsed, it is put in a dish and covered with water. Half a tablet of Hypax or other hypo eliminator is put in one corner until all has been dissolved; the negative is then rinsed in clean water, and the hypo will have been eliminated.

With some eliminators extreme caution is necessary, because they cause the film to frill at the edges, or even to come off altogether if the plates be left long in the liquid.

#### FIXING BATH.

A good fixing bath is made of four ounces hypo dissolved in a pint of water. Vertical fixing in a trough capable of fixing six negatives at a time is recommended. After many plates have been fixed

a dirty deposit will be found at the bottom of the trough. The liquid should be examined in full light after all the holders are removed, and if it is muddy at the bottom it should be thrown away and fresh made. With this precaution the holders and fixing solution may be left in the vessel after use, so that they are always ready; but hypo is very cheap, and it is false economy to use the same solution too often.

Negatives improperly exposed or developed may appear quite black and opaque when examined only on the surface of the plate before fixing, yet after fixing will be quite thin.

Opacity should be judged by holding the negative up to the light. When washed and dried the negative may be varnished if it is likely that it will be much used, otherwise varnishing is not necessary.

A good method of preserving negatives, and at the same time of providing a ready method of selection, is to put each one in an envelope with a consecutive number outside. These may be stored in disused dry plate boxes, outside of which should be boldly printed the numbers of the slides therein. For example, the first box will be 1 to 12, the second 13 to 24, and so on.

A book index will facilitate reference. Each envelope may have also written upon it the full particulars of exposure, though this may be ob-

tained from the exposure book. This system may be extended still further by devoting certain numbers to certain classifications. Thus all negatives of diatoms may be put in one box, insects in another, anatomical subjects in a third, and so on. The advantage is so great and the trouble so little that it is worth the doing.

When the negative has been stained yellow, and it is desired to remove this, it may be immersed in a solution of citric acid and alum—

|             |    |    |    |                      |
|-------------|----|----|----|----------------------|
| Alum        | .. | .. | .. | $\frac{1}{2}$ ounce. |
| Citric acid | .. | .. | .. | $\frac{1}{2}$ „      |
| Water       | .. | .. | .. | 10 ounces.           |

The stain is not always a disadvantage, for it may actually improve the printing capacity of the negative. After the clearing process the plate must be again washed.

Small holes or clear spots are caused by dust, and larger spots probably by air bubbles in the developer. These may be painted out with a small brush charged with colour.

When the negative is too thin it may be altered by intensification, and its printing quality greatly improved.

But intensification is only recommended when the trouble of taking a fresh negative is too great. The photo-micrographer is in a different position from the landscape photographer, who cannot

easily revisit the scene of his subject under the same conditions of light and weather, whereas the microscopist can reproduce it at pleasure.

Intensification should only be regarded as a makeshift. Mercuric chloride is a deadly poison which should be kept under lock and key, and not be brought into contact with the fingers. After the negative has been freed from hypo it may be placed in the following solution until the film becomes white :

|                     |       |                      |
|---------------------|-------|----------------------|
| Mercuric bichloride | ..    | $\frac{1}{2}$ ounce. |
| Hydrochloric acid   | ..    | $\frac{3}{4}$ dram.  |
| Water               | .. .. | 10 ounces.           |

It is then thoroughly washed and redeveloped with a weak solution of ammonia, or any ordinary developer, which will darken the film. It is again well washed and dried.

Over-dense negatives may be reduced in opacity by immersion in equal parts of fresh fixing bath (hypo) and water and a few drops of potassium ferricyanide solution. If the reduction be too slow, more ferricyanide solution may be added. The plate should be lifted out repeatedly for examination, as the action is generally rapid. It is then washed and dried.



## CHAPTER XI.

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PRINTING ON P.O.P.—TONING.—COMBINED TONING  
AND FIXING BATH.—BROMIDE PRINTING.—  
DEVELOPMENT. — PLATINUM PRINTING.—  
SPOTTING PRINTS.—ALBUMS.

Printing-out paper, popularly known as P.O.P., does not show microscopic objects to the best advantage. It is extremely useful for taking trial prints, however, and it is also in great favour with amateur photographers, who consider it the easiest process. A few words, therefore, about it will not be out of place. It is never permanent, and although volumes are written about toning and fixing in separate processes, much trouble will be saved by adopting a single solution for both fixing and toning. The great advantage of this paper is that the result can be seen and printing stopped at the right moment.

The paper is laid on the negative, glossy side of paper in contact with film side of negative, and placed in a printing frame for exposure to daylight, though not to direct sunlight, unless with very dense negatives. The print should be slightly darker than the finished print is intended to be, owing to loss of colour in fixing.

The handling of the paper and inspection of prints should be done in subdued light. After printing is completed, the paper is put in a combined toning and fixing solution until the desired tone is obtained, and then is washed thoroughly in running water, or by eight changes of water, allowing five minutes soaking between each change. Every maker of paper issues full instructions with each packet, but, as nearly all differ, the reader should buy a bottle of combined fixing and toning solution from any photographic dealer, and simply wash his prints well after they come out. If the reader desires to prepare his own solution, the following formula may help him :

**A GOOD COMBINED TONING AND FIXING BATH.**

|                 |    |    |    |            |
|-----------------|----|----|----|------------|
| Hypo            | .. | .. | .. | 1½ ounces. |
| Citric acid     | .. | .. | .. | 20 grains. |
| Acetate of lead | .. | .. | 20 | „          |
| Water           | .. | .. | .. | 8 ounces.  |

Dissolved in the order given, and allowed to stand twenty-four hours. Pour off only the clear liquid for use, and then add one grain of gold chloride dissolved in a little water.

This mixture gives a fine range of tones for landscape prints, and will keep a long time. Also it may be used repeatedly until exhausted.

If the toning and fixing be not carefully watched, a loss of fine detail may result, which,

though immaterial in a pictorial print, might utterly spoil a photo-micrograph. Yet it is all-important that both fixing and washing be thorough if anything like permanence be desired. This somewhat unfavourable feature of bleaching out may nevertheless be utilised to advantage in prints from thin negatives where the background is fogged and contrast not satisfactory, as the loss of colour helps one to obtain the best print possible under the circumstances.

Details on P.O.P. are brought out with greater clearness by a process known as "squeegeeing." This puts a high polish on the paper, and gives a transparent appearance to the shadows. After the final washing is completed, the wet prints are laid face downwards on a piece of clean smooth glass which has been previously polished with French chalk, and lightly pressed in contact with a roller, or flat "squeegee," to get rid of any air bubbles. Run over the back of prints with a piece of blotting paper to remove as much moisture as possible, and set up to dry. Probably the prints will fall off by themselves when dry; but, if not, the point of a knife inserted at one corner will enable them to be separated easily from the glass. On no account attempt to strip them until perfectly dry.

The little clips similar to clothes' pegs are useful for drying the prints. The paper is gripped at one

corner and suspended from a line until dry. Printing frames should have open ends to enable the paper to be raised for examination with ease when the half-back is folded over on its hinge. Some cheap frames have a deep recess, into which the negative and paper drop as into a box, making it extremely difficult to inspect the process of printing without creasing the paper in the endeavour to raise it. A mask with an opening of a suitable size and shape placed between the negative and the paper will give a neat finish to the print.

The print from a negative that happens to be too dense at one end or too thin at the other may be improved when using gaslight paper by simply holding the negative at an angle during exposure to the light, the thin part, of course, being held to slope away from the flame.

Bromide paper is the quickest for microscopic work, and can be done by gaslight. It gives a contrast of velvety black and white, but the picture is not visible after exposure until developed. More uniform results may be obtained from artificial light than from daylight, if several prints are to be taken from one negative, because the correct exposure, having once been ascertained, can be repeated.

The Velox carbon matt is especially suitable for the purpose, being a slow paper capable of



development without a dark room lamp, but it is decidedly advisable to work with a good lamp that gives plenty of safe light. When held flat in the hand, bromide paper will curl slightly with the sensitised surface inside. Wetting the corners with thumb and finger in order to distinguish the different sides is not a clean habit, but the paper may be held between the teeth at one corner, when the sensitised surface will stick to the teeth.

The exposure depends on the negative, but for average density the Velox carbon takes twenty seconds at six inches from a No. 5 burner. A thin negative should be held further away from the light ; a dense one, nearer. The frame is best kept between the eyes and the gas to shade the eyes during exposure, and if frequent exposures are made at one time, neutral tint spectacles during the time the light is full on will be found a relief. Having made the exposure and lowered the light, the paper is taken from the frame and dipped into clean water, so that it will lie flat in the developing dish. The developer is swept over the paper, keeping it freely on the move until the required depth of tone be reached, when the paper is rinsed in clean water and immersed edgewise,

face up, in the fixing bath made up as follows :

FIXING BATH FOR BROMIDE PAPER.

|       |    |    |    |           |
|-------|----|----|----|-----------|
| Hypo  | .. | .. | .. | 4 ounces. |
| Water | .. | .. | .. | 16 „      |

To this are added—

|                 |    |    |          |
|-----------------|----|----|----------|
| Sodium sulphite | .. | .. | 1 dram.  |
| Acetic acid     | .. | .. | 6 drams. |
| Alum            | .. | .. | 1 dram.  |

Dissolved in  $1\frac{1}{4}$  ounces of water.

The prints are kept moving a few moments, and afterwards allowed to remain fifteen minutes. An hour's washing in running water, or in eight changes of water, as before described, completes the process. A thorough washing should be given. The above bath keeps clean much longer than a simple hypo and water bath, and can be used time after time until exhausted.

If the brand of bromide paper shows blisters during development, try a developer free from caustic alkali.

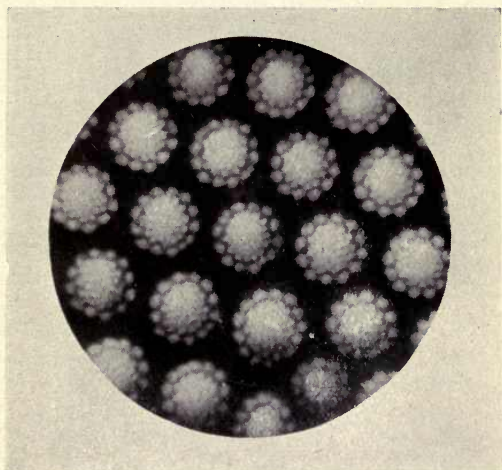
Platinotype printing is at once the simplest, most permanent, and most effective of all processes. Good negatives yield prints equal in beauty to a fine steel engraving, with rich gradations of tone very pleasing to behold. The whole process can be completed on a bright day in a little over an hour, though on dark days the printing is slow. Moisture is the chief preventive of successful work ;

ELEMENTARY PHOTO-MICROGRAPHY.  
PLATE XIV.

BACTERIA.  
 $\frac{1}{12}$  OIL IMMERSION.



*Bacillus Subtilis.*  $\times 1000$ .



*Coscinodiscus Asteromphalus.*  $\times 1500$ .





therefore paper, wood frames, and place of exposure must be dry.

The platinotype paper itself is supplied in sealed tins, twenty-four sheets, quality A A,  $4\frac{1}{4} \times 3\frac{1}{4}$  in., for 1/6, from which it should be removed for preservation to a special tin tube having a false bottom, under which calcium chloride is kept to absorb any moisture, and the joints of this tube are further protected by a wide rubber band. Thus protected, the paper will keep in good condition many months. The lemon-coloured surface of platinum paper is more sensitive to light than is that of P.O.P.; consequently, the placing of the paper in the frames, the examination of prints, and development must be done in dull light. After the sheet of platinotype paper is put on the negative, it is desirable, though not essential, to add a protecting sheet of rubber or waterproof paper before fastening the back of the printing frame. During exposure, which must be by daylight, an occasional peep at the paper will show how far printing has proceeded. The image is only faint grey when finished, but every detail should be seen, however feeble. If there be any part of the print that should be pure white when finished, the attention should be fixed on that spot, and its tint compared with that of the edges of paper. So long as this is the same lemon colour, it may be gathered

that printing is not carried too far. As development is very rapid, the exposure must be correct to get good results. After a few trials it will not be found at all difficult to determine when to stop printing. The developing bath, which should not be below 60° F., is made up of—

Neutral potassium oxalate .. 1 ounce.

Oxalic acid (saturated solution)

1 part to 20 parts of developer.

Water .. .. 10 ounces.

This is a stock solution, and may be bottled for future use. The paper is floated on the bath, face downwards, turned quickly over, and development watched. A black and white image will rapidly appear, and when sufficient depth of tone is obtained, the print may be removed to a bath composed of—

Water .. .. 10 ounces.

Hydrochloric acid .. 1½ drams.

Any of the lemon colour left will here be cleared away, and black and white tones only remain. After five minutes in this bath the prints are transferred to a similar but rather more dilute bath for ten minutes, then to three baths of clean water for ten minutes each, into the second of which a few grains of sodium carbonate have been added to neutralise any acid left in the prints.

Wollf's "indelible railway pencil" is excellent for any retouching with either bromide or platino-type prints. Photo-micrographs kept in a special album having only one print on a page show to better advantage than when mixed with others of a miscellaneous kind.

## CHAPTER XII.

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LANTERN SLIDE MAKING. — FRAME. — TESTING SLIDES.—COLOURING LANTERN SLIDES WITH ANILINE DYES.—TONING BATHS FOR VARIOUS COLOURS.—RULE FOR FINDING DISTANCE OF LANTERN FROM SCREEN.

Lantern slides, if well made, give pleasure to young and old, whilst their educational value is universally acknowledged to be of great importance. They no longer remain the monopoly of the travelling entertainer, since slides are now produced by almost every scientific society. Equally helpful are they in the private house, where one who has learnt how to make them may enjoy many a winter evening, even with only himself for audience. To one who has mastered the art of negative making no difficulty will be experienced, for the developing of lantern slides is similar, except that a positive image appears instead of a negative. This fact renders it much fuller of interest, as the gradual unfolding of the complete image never fails to delight the operator. The standard size for English slides is  $3\frac{1}{4} \times 3\frac{1}{4}$  in., a suitable size for contact printing from a  $4\frac{1}{4} \times 3\frac{1}{4}$  in. negative.

The usual slide-making frame consists of a board having a  $3\frac{1}{4}$  in. square hole in the centre, into



which the sensitive plate fits. The negative is placed film side to this hole, and is held against the cloth-faced board by springs in such a way that the negative may be moved in any direction to bring the right position opposite the centre. The dry plate is then put on, with film side against film side of negative, and covered with a wood block the same size, which again is pressed by a spring to keep the negative and plate in contact. If any difficulty be experienced in discovering the film side, it may be removed by simply breathing upon the slide, when the glass side will be at once clouded over or steamed by the condensed moisture, but the film side will remain dry and unaffected.

The exposure varies with the plate used. Ilford "Special" lantern plates for warm and cold tones require twenty seconds at eighteen inches from an ordinary gas bat's-wing burner. Ilford "Alpha" for red and brown tones, two minutes at six inches from the burner. For slides with black ground or contrasty effects, the Cadett "Black Tone" plates give excellent results. Exposure, five seconds at twenty-four inches from gaslight.

Development and fixing are the same as for negatives, but there is more necessity for rinsing lantern slides in clean water after development and before fixing to avoid stains which otherwise might occur.

The least fogging of the lights, it should be noted, will spoil the slide, and the image must stand out well defined on a perfectly transparent background. Spoiled plates make good cover glasses, if stripped of gelatine by steeping in boiling water and soda. When the plates are ready for mounting, a square or circular mask is placed between the cover and picture. If there is room on the margin of the mask, which is usually black, the title may be written upon it with white ink, not forgetting to put a white spot in each top corner when looking at the picture the right way about. These are for the guidance of the lanternist, who puts the slide into the lantern upside down with the spots toward the condenser. Nothing is more awkward for both audience and operator than pictures projected in a wrong position.

It often happens that a slide which appears all right by mere daylight inspection will show very badly when enlarged on the screen through the lantern to a roft. disc. Then any defects in focus are plainly visible, and if the slide be too dense or too thin, it is at once apparent. It is therefore advisable before exhibiting any slide in public to have it tested. If not already a member of a local photographic society, here is an inducement to join one, because most societies give special opportunities for testing the slides of members

with a powerful light through a good lantern, in addition to other advantages.

A lanternist can often improve the picture from a thin slide by lowering his light, so that the image on the screen gains contrast by a less brilliant light.

#### COLOURING LANTERN SLIDES WITH ANILINE DYES.

Some objects need colour to differentiate various parts, and it is quite easy to make a lantern slide as effective by means of aniline dyes as a double or single stained mount from which the photograph has been taken. Or the natural colours of any object may be faithfully reproduced for pictorial effect.

The points to be remembered are few and simple. Avoid fugitive dyes, and use only transparent colours. An excellent outfit is supplied by the Vanguard Company for 1s. 6d.

With the slide on a retouching desk, wash over the gelatine film with a large sable brush charged with clean water, or soak the slide in water two or three minutes, to remove greasiness and prevent blisters, then leave it till it shows a dull damp surface. The slide will now absorb colour without any tendency to overrun the boundary lines. Work with a hand magnifying glass for details, and use two brushes—one charged with colour, and the other just moistened with clean water for



absorbing surplus dye, softening edges, or grading from dark to light tones. Get intensity by repeated washes of diluted colour rather than with full strength, and do not clog details. If slide be too crude or over coloured, soaking in water will remove the excess.

Compound colours may be obtained by superposed washes of the component primaries, as, for example, green will be shown by a wash of blue over yellow ; but often the blended tints may be secured by directly mixing the requisite colours. A little practice will enable anyone with a knowledge of water-colour painting to produce creditable results.

#### TONING BATHS FOR LANTERN SLIDES.

Although a series of good black or rich brown slides would satisfy most tastes, it is occasionally necessary to emphasise some particular point in an object by a suggestion of its natural hue ; and for this purpose various toning baths may be used by which almost any desired colour may be got. A few coloured slides, moreover, judiciously interspersed, will be a distinct relief and pleasure to most audiences, especially when the colour helps to convey a more faithful conception of the object than could be done in black and white, and they will prevent the monotony usually attendant on a continuous display of uniform tones.



Most plate makers give instructions for cold and warm tones that may be obtained by simple development, adopting normal exposure and developer for cool tones, and longer exposure and weaker developer with more liberal use of restrainer for warm tones; but outside this limited range recourse must be had to chemical baths for any special portion of the spectrum.

The following methods of treatment will give a varied field of choice, and yield results in accordance with the wish of the operator. The quantities given are for two or three slides only, but any number may be treated by a proportionate increase in the volume of the bath. Commence always with the slide in a dry state.

*Blue-black and Purple.*

|                          |               |         |
|--------------------------|---------------|---------|
| Sulphocyanide ammonium . | 6             | grains. |
| Water .. .. .            | 2             | ounces. |
| Gold chloride .. .. .    | $\frac{1}{2}$ | grain.  |

Immerse until the desired tone is reached, then wash and dry.

*Red and Copper.*

A.

|                           |                |         |
|---------------------------|----------------|---------|
| Potassium ferricyanide .. | $1\frac{1}{2}$ | grains  |
| Water . .. .              | $1\frac{1}{2}$ | ounces. |

B.

|                          |    |         |
|--------------------------|----|---------|
| Uranium nitrate .. .. .  | 3  | grains. |
| Ammonium sulphocyanide . | 15 | „       |

|             |    |    |    |            |
|-------------|----|----|----|------------|
| Citric acid | .. | .. | .. | 3 grains   |
| Water       | .. | .. | .. | 1½ ounces. |

Equal parts of A and B.

After toning, clear by rinsing in dilute solution of carbonate of soda. Wash and dry.

*Sepia.*

A.

|                 |    |    |    |           |
|-----------------|----|----|----|-----------|
| Uranium nitrate | .. | .. | .. | 2 grains. |
| Acetic acid     | .. | .. | .. | 18 drops. |
| Water           | .. | .. | .. | 1 ounce.  |

B.

|                      |    |    |    |           |
|----------------------|----|----|----|-----------|
| Potass. ferricyanide | .. | .. | .. | 3 grains. |
| Acetic acid          | .. | .. | .. | 18 drops. |
| Water                | .. | .. | .. | 1 ounce.  |

Equal parts of A and B. Wash and clear in weak acetic acid bath. Wash again in clean water and dry.

*Brown.*

Bleach with mercuric chloride. Wash and immerse in 20% solution of hypo.

Thoroughly wash and then dry.

*Blue.*

Bleach in 10% solution potass. ferricyanide. Wash ten minutes, then immerse in 5% solution of ferric chloride. Wash and dry.

*Green.*

The slide may be stained with aniline dye when it is not necessary to preserve high lights, or the following bath can be tried:

|                      |    |    |           |
|----------------------|----|----|-----------|
| Uranium nitrate      | .. | .. | 6 grains. |
| Potass. ferricyanide | .. | 5  | „         |
| Acetic acid          | .. | .. | 1 drop.   |
| Water                | .. | .. | 1 ounce.  |

Dissolved in the order given. The slide must be quite free from hypo before treatment. Wash and then immerse in one ounce water in which five grains ferric chloride are dissolved.

Again wash and dry.

The "Tabloid" toners by Burroughs and Wellcome are very convenient and easy to use.

#### RULE FOR FINDING DISTANCE OF LANTERN FROM SCREEN.

Add one to the number of times the slide is to be enlarged, and multiply by the focus of lens in inches. The answer will be in inches.

EXAMPLE: What distance should lantern, with 8in. focus lens, be from screen to give a 10ft. picture?

If the lantern slide has a clear opening of 3in., then the magnification of a 10ft. picture would be forty times. Therefore  $(40 + 1) \times 8 = 328\text{in.}$ , or 27ft. 4in.

## GLOSSARY.

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**ACHROMATIC OBJECTIVES** do not unite all the coloured rays in an image, but leave a secondary spectrum. The spherical aberration is corrected for rays of only one colour.

**APOCHROMATIC OBJECTIVES** give images free from colour, and are corrected for spherical aberration for different parts of the spectrum.

**ANGULAR APERTURE.** The angle of a cone of light that is received by the objective from a point on the object.

**APLANATIC.** Free from spherical aberration, or the quality that brings all rays to one focus.

**APLANATIC APERTURE.** The N.A. of the largest solid cone of light which can be transmitted by the condenser.

**BULL'S-EYE.** A plano-convex lens, usually mounted on a pillar with ball and socket joint. Sometimes called an auxiliary condenser.

**COMPENSATING EYEPIECES** correct colour defects in the objectives.

**CONDENSER.** A system of lenses for the substage to collect the light and focus it upon the specimen. Not to be confounded with BULL'S-EYE.

**CAMERA LUCIDA.** A prism or reflector attached to the eyepiece of microscope which enables the observer to sketch the enlarged image on paper.

**COMPLEMENTARY COLOURS.** Pairs of colours which, when mixed, produce white or grey. With pigments the primary colours are taken to be red, blue, and yellow; but with coloured light, red, blue, and green. If one primary colour be selected, its complementary will be that made by the union of the remaining two colours. Thus yellow would have for its complementary a mixture of blue and red, or violet.

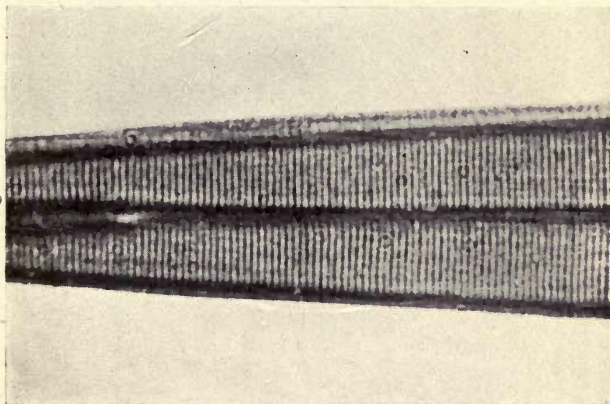


ELEMENTARY PHOTO-MICROGRAPHY.  
PLATE XV.



Crystal of Sal-ammoniac by DOUBLE LIGHT.

Enlarged from negative.  
TAKEN WITH OIL LAMP.



*Amphipleura Pellucida*.  $\times 4000$ .  
Showing lines breaking into dots.  
Exposure, One Hour.

$\frac{1}{2}$  oil immersion, 1.4 N.A.

Condenser oiled to the slide.



**COLOUR SCREEN.** A coloured glass or liquid used as a filter to intercept colours not required.

**CHROMATIC ABERRATION.** Unequal refraction of various colours which do not focus at one point, but give prismatic colouring of the image.

**CRITICAL LIGHT.** Critical light is given by the substage condenser when both flame of lamp and objective are focussed on the slide in the same optical axis. It is essential for high power work.

**CORRECTION COLLAR.** A contrivance for separating the lenses in an objective or bringing them nearer together to correct for different thicknesses of cover glass. For thick covers the lenses are brought nearer, and for thinner ones separated. Or the correction may be made by shortening the tube for thicker covers, or lengthening it for thinner ones.

**DAVIS SHUTTER.** An iris diaphragm used like a nose-piece at the end of body tube, by means of which aperture can be modified from the back of objective. It is useful for getting penetration and in dark ground illumination.

**DEFINITION.** Sharpness and clearness of image, which must be free from blur or fog.

**DIAPHRAGM.** A plate with circular hole to cut off marginal beams of light.

**DIFFRACTION.** Caused by an opaque body in the path of light, which deflects the rays from their course and causes them to interfere with one another.

**EYEPieces, DEEP AND SHALLOW.** A deep eyepiece has greater magnifying power than a shallow one, but the terms deep and shallow refer to the amount of curvature of lenses, and not to the distance between them. Eyepieces are also called high and low, the last giving a lower amplification of the image than the first.

**FIELD,** The actual area presented at once to the view of the observer.

**FOCUS OF OBJECTIVE** must not be taken to mean that the focus is the distance between the objective and the cover glass. It refers to the magnification of a single lens of that focus, and is used for comparison only. Focus of single lens is distance from optical centre to point where rays meet.

**IMMERSION OBJECTIVES** are used with a fluid, usually cedar oil, to connect the lens of the objective with the cover glass of the specimen under examination, and have greater aperture than would be possible with dry lenses, therefore giving greater resolving power.

**IRIS DIAPHRAGM.** A series of small shutters arranged to give a circular opening, the size of which may be varied to give different apertures at will.

**INTENSITY OF LIGHT** diminishes as the square of the distance from the radiant point.

**MONOCHROMATIC LIGHT.** Light of one colour and uniform wave length. Images formed by waves of different lengths may destroy each other. The longest wave is red, and the shortest violet. Every colour has a different wave length, and the separating power of objectives increases as the length of light waves diminishes—that is, if the wave length be reduced, it is equivalent to increase of aperture.

**MALTWOOD FINDER.** A series of squares with vertical and horizontal numbers photographed on a glass slip to be placed on microscope stage for recording and finding the position of any desired object on a slide.

**MECHANICAL TUBE LENGTH.**—The distance from the end of tube receiving the eyepiece to the shoulder against which the objective will be screwed. The Continental pattern is usually 160 mm. (about  $6\frac{1}{4}$  inches),



and the English pattern 250 mm. (about 10 inches). Objectives should be used which are designed for the particular length of tube adopted.

**MICROMETER.** A slip of glass ruled to scale, generally hundredths or thousandths of an inch. Made for use on the stage of microscope and also for the eyepiece.

**NUMERICAL APERTURE (N.A.)** A term employed for measuring the ray-receiving capacity of an objective. Must not be confounded with diameter or size, for, unlike the telescope, the smaller objectives have usually the larger aperture. The comparison of apertures is made not by angles but by their sines.

**OPTICAL TUBE LENGTH.** Usually 20 mm. more than the mechanical tube length. Measured from the diaphragm of the eyepiece to the upper focal plane of objective.

**OBJECT GLASSES (O.G.), OBJECTIVES OR POWERS.** The lenses used for the first magnification of the image. In selecting objectives the following points should be considered: Definition, aperture or resolving power, depth of focus or penetration, working distance or actual distance between front lens and object, flatness of field, and freedom from colour.

**OBLIQUE ILLUMINATION.** Light passed to the object from only one edge of the condenser at an angle with axis of microscope.

**OPTICAL CENTRE OR FOCAL CENTRE.** A point from which focal measurements must be made. Sometimes it is within the lens and sometimes outside.

**OCULAR.** (See EYEPIECE.)

**ORTHOCHROMATIC.** The quality of rendering correct colour values.

**PENETRATION OR DEPTH OF FOCUS.** The power to give a distinct image above or below the exact focal plane.

The penetrating power of an objective decreases with the increase of both numerical aperture and magnifying power, inversely as the numerical aperture and also inversely as the square of the magnifying power.

**POWER.** Magnifying powers of lenses are estimated by comparing their focal lengths with the distance of distinct vision, and this has been generally agreed should be arithmetically expressed by reference to visual magnitude seen at 10in. distance. Thus 10in. divided by the focal length will be approximately the magnifying power of the lens, *e.g.*, a 1in. objective should magnify 10 diameters,  $\frac{1}{2}$ in. 20 diameters,  $\frac{1}{4}$ in. 40 diameters. More nearly correct if the magnifying power of a lens at any tube length is obtained by dividing the distance of projection by the focus and subtracting one. Thus a 1in. lens at 10in. distance will magnify 9 times.  $\frac{10}{1} - 1 = 9$ . The total power

of the microscope is found by multiplying the initial enlargement of the image by the further magnifying power of the eyepiece. Thus an objective magnifying 20 diameters used with the A eyepiece, usually magnifying 5 diameters, will give  $20 \times 5 = 100$  diameters.

**POLARISCOPE.** An instrument for polarising and analysing the light. Generally consisting of Iceland spar prisms mounted for easy attachment to the microscope. The polariser underneath the object and the analyser above the objective.

**PROJECTION, OCULAR.** An eyepiece used for photo-micrography or for demonstration purposes, to throw the enlarged image on to a screen.

**REFLECTED LIGHT OR OPAQUE ILLUMINATION.** Light that passes into the microscope by reflection from the front of the object viewed.

**REFRACTION.** The deflection or change of direction of rays of light by a transparent body through which they pass.

**RESOLVING POWER.** The power to separate component parts of a body dependent on, and directly proportional to, the N.A.

**SPHERICAL ABERRATION** exists when marginal and central rays do not meet at one point, or focus, but give a blurred and indistinct image.

**SPECTRUM.** A coloured band resulting from the decomposition of light. The colours are red, orange, yellow, green, blue, indigo, and violet.

**SELENITE.** A transparent mineral used in thin plates for varying the colours with a polariscope.

**SHARPNESS OF IMAGE AND CIRCLE OF LEAST CONFUSION.** An image would be sharp if the rays were correctly focussed; but as lenses are not free from error, a permissible amount of aberration called the circle of least confusion is recognised, viz.,  $\frac{1}{100}$  in. diameter. That is, a point may be blurred by the lens to the extent of  $\frac{1}{100}$  in. without spoiling the picture.

**SPOT LENS.** A lens for the substage with blacked centre and clear marginal ring, used for dark ground illumination.

**STOPS.** Discs of metal of various shapes for insertion in the condenser.

**STANDARD SIZES.** Certain standards have been adopted for eyepieces, objectives, and condensers, so that the products of different makers may be interchangeable. Eyepiece, students' size, .9173 in. diameter (23.3 mm.) Larger stands, 1.27 in. (32.258 mm.) Objective, .7967 in. (thirty-six threads). Condenser, 1.527 in. (38.786 mm.)

## APPENDIX.

---

When photographing without microscope, and using a lens in the adapter on front of camera, the following rules will be useful.

TO FIND MAGNIFICATION WITH GIVEN CAMERA LENGTH AND FOCUS OF LENS—

Divide the length of camera by the focus of lens, and subtract one from the result, which will give the enlargement in diameters.

WITH GIVEN FOCUS TO FIND CAMERA EXTENSION FOR REQUIRED MAGNIFICATION—

Add one to the number of diameters wanted, and multiply by the focus of lens.

TO FIND WHAT FOCUS LENS IS REQUIRED FOR GIVEN MAGNIFICATION AND CAMERA LENGTH—

Add one to the number of diameters wanted, and divide the camera length by this number, which will give the focus of lens required.

### NEGATIVE ENLARGING.

If for exhibition or other purposes it is desirable to have a print on a larger scale than usual, the following formula will enable one to fix the relative distances between the negative and lens, and bromide paper and lens. In all cases the size of the enlarged picture bears the same proportion to the size of negative that the distance of the enlarged picture from lens bears to the distance



of negative from lens. Thus if a negative be enlarged twice, the distance of image from lens will be twice that of the negative from lens.

D. Distance of negative from lens.

P. Distance of image from lens.

N. Number of times negative is to be enlarged.

F. Focus of lens.

$$P = (N + 1) F$$

$$D = F + \frac{F}{N}$$

#### CONJUGATE FOCI.

When one of these distances is known, it is easy to find the other, which is called the conjugate focus.

ONE OF THE CONJUGATE FOCI BEING GIVEN, TO FIND THE OTHER.

F. Focus of lens.

D. Distance from lens when object is on the known side.

$$\frac{D \times F}{D - F} = \text{conjugate focus.}$$

*Example.*—What should be the distance of negative from lens of 6in. focus to give a three-fold enlargement? By formula :

$$F + \frac{F}{N} = D.$$

$$6 + \frac{6}{3} = 8 \text{ inches.}$$

Distance of bromide paper from lens comes out by formula :

$$(N + 1) F = P.$$

$$(3 + 1) 6 = 24 \text{ inches.}$$

# PRICES OF MICROSCOPE OBJECTIVES AND ACCESSORIES.

---

|   |    |    |    |         |        |
|---|----|----|----|---------|--------|
| 2in. and 1in. objective   | .. | .. | .. | each    | 20/-   |
| $\frac{1}{2}$ in. and $\frac{1}{4}$ in. objective                         | .. | .. | .. | each    | 25/-   |
| $\frac{1}{8}$ in. objective   | .. | .. | .. | ..      | 30/-   |
| $\frac{1}{12}$ in. oil-immersion objective                                | .. | .. | .. | ..      | £5 0 0 |
| Eyepieces—A, B, C   | .. | .. | .. | each    | 10/6   |
| Projection eyepiece   | .. | .. | .. | ..      | 40/-   |
| Parabolic side silver reflector   | .. | .. | .. | ..      | 23/-   |
| Vertical illuminator  | .. | .. | .. | ..      | 10/6   |
| Davis shutter   | .. | .. | .. | ..      | 15/-   |
| Bull's-eye  | .. | .. | .. | ..      | 15/-   |
| Camera lucida   | .. | .. | .. | ..      | 6/-    |
| Focussing glass   | .. | .. | .. | ..      | 5/-    |
| Adjustable oil lamp, with metal chimney                                   | .. | .. | .. | ..      | 25/-   |
| Ditto, combined with bull's-eye   | .. | .. | .. | ..      | £4 4 0 |
| Incandescent gas lamp   | .. | .. | .. | ..      | 10/-   |
| Stage micrometer, 1-100in. and 1-1000in.                                  | .. | .. | .. | ..      | 5/-    |
| Eyepiece micrometer   | .. | .. | .. | ..      | 5/-    |
| Polariscope   | .. | .. | .. | ..      | 25/-   |
| Selenite plates   | .. | .. | .. | each    | 1/6    |
| Substage condenser, chromatic   | .. | .. | .. | ..      | 35/-   |
| Ditto, achromatic   | .. | .. | .. | ..      | 75/-   |
| Iris diaphragm  | .. | .. | .. | ..      | 25/-   |
| Magnesium clockwork lamp  | .. | .. | .. | ..      | 20/-   |
| Magnesium ribbon  | .. | .. | .. | per oz. | 1/6    |
| Acetylene lamp  | .. | .. | .. | ..      | 15/-   |
| Quarter-plate camera ( $4\frac{1}{4} \times 3\frac{1}{4}$ ), without lens | .. | .. | .. | ..      | 20/-   |
| Limelight jet, regulator and gauge, tubing, and oxygen cylinder           | .. | .. | .. | ..      | 90/-   |
| Dark-ground illuminator for high powers                                   | .. | .. | .. | ..      | 40/-   |
| Macro illuminator for large field with low powers                         | .. | .. | .. | ..      | 30/-   |

## USEFUL BOOKS.

| Title.   | Author.                | Publisher.                 | Price. |
|--|------------------------|----------------------------|--------|
| <i>The Microscope and its Revelations</i>          | Dallinger .            | Churchill .. ..            | 28/-   |
| <i>Popular Handbook to the Microscope</i>          | Wright ..              | R. T. S. .. ..             | 2/6    |
| <i>Practical Microscopy</i> .. ..                  | Davis ..               | Allen .. ..                | 7/6    |
| <i>The Young People's Microscope Book</i>          | Sedgwick .             | Culley .. ..               | 3/6    |
| <i>Micrographic Dictionary</i> ..                  | Griffith and Henfrey   | Van Voorst ..              | 52/6   |
| <i>Guide to Science of Photo-micrography</i>       | Bousfield .            | Churchill .. ..            | 6/-    |
| <i>Microscopy</i> .. .. .                          | Spitta ..              | Murray .. ..               | 12/6   |
| <i>Photo-micrography</i> .. ..                     | Spitta ..              | Scientific Press .         | 12/6   |
| <i>Metallography</i> .. .. .                       | Hiorns ..              | Macmillan ..               | 6/-    |
| <i>Mounting Microscopic Objects</i>                | Davies ..              | Allen .. ..                | 2/6    |
| <i>Principles of Microscopy</i> ..                 | Sir A. E. Wright       | Constable . ..             | 21/-   |
| <i>The Microscope</i> .. .. .                      | Hogg ..                | Routledge ..               | —      |
| <i>Modern Microscopy</i> .. ..                     | Cross and Cole         | Bailliere, Tindal, and Cox | 4/-    |
| <i>Practical Photo-micrography</i> .               | Barnard ..             | Arnold .. ..               | 15/-   |
| <i>Photo-micrography</i> .. ..                     | Pringle ..             | Iliffe .. ..               | 3/6    |
| <i>Practical Microscopy</i> .. ..                  | Scales ..              | Tindal and Cox .           | 3/6    |
| <i>Life in Ponds and Streams</i> .                 | Furneaux .             | Longmans Green             | 6/-    |
| <i>Through a Pocket Lens</i> ..                    | Scherren ..            | R.T.S. .. ..               | 2/6    |
| <i>Ponds and Rock Pools</i> .. ..                  | Scherren ..            | R.T.S. .. ..               | 2/6    |
| <i>Common Objects of the Microscope</i>            | Wood ..                | Routledge . ..             | 3/-    |
| <i>Optics of Photography</i> .. ..                 | Taylor ..              | Whittaker . ..             | 3/6    |
| <i>Optical Projection</i> .. .. .                  | Wright ..              | Longmans Green             | —      |
| <i>Light</i> .. .. .                               | Wright ..              | Macmillan . ..             | —      |
| <i>Cantor Lectures on Theory of the Microscope</i> | Beck.. ..              | Royal Society of Arts      | 1/-    |
| <i>The Microscope</i> .. .. .                      | Van Heurck             | Crosby Lockwood            | 18/-   |
| <i>Evenings at the Microscope</i> ..               | Gosse ..               | S.P.C.K. .. ..             | 5/-    |
| <i>Marvels of Pond Life</i> .. ..                  | Slack . ..             | —                          | —      |
| <i>Ponds and Ditches</i> . .. .                    | Cooke ..               | S.P.C.K. .. ..             | —      |
| <i>Photo-micrography</i> . .. .                    | Wratten and Wainwright | Kodak, Ltd. ..             | —      |

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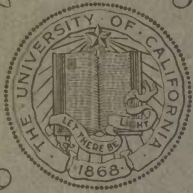
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